THE AUTHORITY ON THE FUTURE OF TECHNOLOGY
November/December 2007
www.technologyreview.com

Technology Review

PUBLISHED BY MIT SINCE 1899

On Wednesday, August 8, not long after the markets closed, 200 of the smartest people on Wall Street gathered in a conference room at Four World Financial Center, the 34-story headquarters of Merrill Lynch. August is usually a slow month, but the rows of chairs were full, and highly paid financial engineers were standing by the windows at the back, which looked out over black Town Cars below and the Hudson River beyond. They didn't look like Masters of the Universe; they looked like members of a chess club. They were "quants," and they had a lot to talk about, for their work was at the heart of the most worrisome summer market in decades.

The Blow-Up

By Bryant Urstadt Page 36

technology
review
Published by MIT

The world is growing by more than 70 million people a year.

So is that a problem, or a solution?

With our planet's population continuing to increase, and the quality of life for millions in the developing world improving daily, our demand for energy is also growing. And to meet everyone's needs 25 years from now may take 50% more energy than we use today.

Finding and developing all the fuel and power we need for our homes, businesses and vehicles, while protecting the environment, could be one of the greatest challenges our generation will face.

The key to ensuring success is found in the same place that created this need: humanity itself. When the unique spirit we all possess is allowed to flourish, mankind has proven its ability to take on, and overcome, any issue. It's a spirit of hard work, ingenuity, drive, courage and no small measure of commitment. To success, to each other, to the planet.

The problem...becomes the solution.

This human energy that drives us to succeed has been there every day since the beginning. And it will be with us to shape many tomorrows to come.

So join us in tapping the most powerful source of energy in the world. Ourselves.

And watch what the human race can do.

Chevron

Human Energy

Contents

Volume 110, Number 6

Features

Forward

Hack

Q&A

Notebooks

Graphic Story

Reviews

Demo

From the Labs

19 Years Ago in *TR*

What's New on Our Website

technologyreview.com/googleearth
In this month's Hack, we dissect the popular online tool Google Earth *(p. 20)*. Experience a fly-through tour for yourself by visiting the *Technology Review* website. Videos show how Google attempts to portray the real world in three dimensions.

technologyreview.com/blog
Technology Review has enlisted new expert bloggers to provide thoughtful commentary on the latest research. Ed Boyden, an assistant professor in the MIT Media Lab and MIT Department of Biological Engineering, blogs about the rapidly developing field of brain engineering. Boyden, a leading innovator in the field, develops and deploys novel tools that analyze and modify brain circuits to help correct aberrant activity. John Maeda, a graphic designer, visual artist, and computer scientist at the MIT Media Lab, offers insight on a unique and eclectic collection of design oddities in his blog, Technohumanism.

technologyreview.com/emtech/videos/
Those who couldn't make it to this year's EmTech, Technology Review, Inc.'s annual conference on emerging technologies, can watch videos of all its workshops, keynote speeches, and breakout sessions online. Even if you did attend EmTech 2007, you might want to catch up on what you missed. It's all here.

technologyreview.com/mars
Technology Review's first graphic story *("Mission to Mars," p. 26)* also gets special treatment online. Watch the story of the *Mars Observer* unfold by scrolling from frame to frame in a Flash application. Got crayons? Download a black-and-white version for your children to color.

Technology
PUBLISHED BY MIT Review

Customer service and subscription inquiries

National: 800-877-5230
International: 386-447-6352
www.technologyreview.com/customerservice
Permissions: 978-750-8400
Reprints: 717-399-1900 x118
MIT Records: 617-253-8270 (alums only)

Technology Review
One Main Street, 7th Floor
Cambridge MA 02142
Tel: 617-475-8000
Fax: 617-475-8043

De Technologia non multum scimus. Scimus autem, quid nobis placeat.

Technology Review, Inc., the authority on the future of technology, identifies emerging technologies and analyzes their impact for technology leaders. Technology Review publishes *Technology Review* magazine (the oldest technology magazine in the world, founded in 1899) and the daily website TechnologyReview.com; it also produces live events such as the Emerging Technologies Conference. Technology Review is an independent media company owned by the Massachusetts Institute of Technology. The views expressed in our various publications and at our events are often not shared by MIT.

It's how Logitech reinvented the remote control.

Harmony 1000

Imagine if you could turn on the TV, start the movie and set up the sound all with one touch of your finger. Imagine one touch to all your entertainment. That's what Logitech imagined. To create their newest activity-based universal remote control, Logitech turned to Freescale. Freescale i.MX applications processors enable multi-functionality with low power consumption, and helped Logitech create a scalable board for future generations. By working with Freescale, Logitech literally put all our entertainment at our fingertips, and made the world a smarter place. freescale.com/smarter

freescale™
semiconductor

Statement required by 39 U.S.C. 3685 showing the ownership, management, and circulation of *Technology Review*, published bimonthly (6 issues), for September 1, 2007. Publication No. 535-940. Annual subscription price $34.00.

1. Location of known office of publication:
MIT, One Main Street, Cambridge, Middlesex, MA 02142

2. Location of headquarters or general business office of the publisher:
MIT, One Main Street, Cambridge, Middlesex, MA 02142

3. The names and addresses of the publisher, editor, and managing editor:
Publisher: Jason Pontin, MIT, One Main Street, Cambridge, Middlesex, MA 02142
Editor: David Rotman, MIT, One Main Street, Cambridge, Middlesex, MA 02142
Managing Editor: Nate Nickerson, MIT, One Main Street, Cambridge, Middlesex, MA 02142

4. The owner is
Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139.

5. Known bondholders, mortgages and other security holders owning or holding one percent or more of total amount of bonds, mortgages, or other securities:
None

6. Extent and nature of circulation:

	Average number of copies of each issue during preceding 12 months	Number of copies of single issue published nearest to filing date
A. Total number of copies:	226,143	223,310
B. Paid and/or requested circulation:		
1. Paid/requested outside-county mail subscriptions:	183,082	180,562
2. Sales through dealers and carriers, street vendors, counter sales, and other non-USPS paid distribution:	11,876	12,498
C. Total paid and/or requested circulation:	194,958	193,060
D. Free distribution by mail:	2,238	2,240
E. Free distribution outside the mail:	6,522	6,916
F. Total free distribution:	8,760	9,156
G. Total distribution:	203,718	202,216
H. Copies not distributed:	22,424	21,094
I. Total:	226,143	223,310
J. Percent paid and/or requested circulation:	95.7%	95.5%

7. I certify that all information furnished on this form is true and complete:
(Signed) Heather Holmes, Director of Circulation

Contributors

Bryant Urstadt wrote this issue's cover story, on Wall Street "quants"—mathematically trained financial engineers and managers—and the role their work played in this summer's

upheaval in the financial markets *("The Blow-Up," p. 36)*. "This was one of the most intimidating pieces I have ever been involved in," says Urstadt. "But as my reporting developed, I noticed that I wasn't alone in my confusion, in that a lot of people were slightly unsure about what was going on in their own domain. It wasn't like people were panicking—it was just that there was a general sense that things were a bit mysterious. One thing was clear, though: these were some of the smartest people I've ever talked to."

Urstadt is a freelance writer whose work regularly appears in *New York*, *Outside*, and *ESPN*.

Asaf and **Tomer Hanuka** illustrated "Mission to Mars," a graphic story written by Erica Naone, which chronicles NASA's various attempts to

explore that planet *(p. 26)*. "There is a sense of the fantastic struggling to coexist with the real, which we found very appealing," says Tomer. "When we thought about the people involved, we imagined geeky kids reading sci-fi novels: now they're all grown up and redefining the future." Tomer and Asaf, who are identical twins, are the creators of *Bipolar*, an award-winning comic-book series. Work they did separately has appeared in the *New Yorker*, *Spin*, *Rolling Stone*, *Time*, and *Forbes*. "We grew up in Israel and spent the majority of our childhood reading comics," says Asaf. "It's very hot in that part of the world, and everything is constantly bathed in yellow. We took four-color trips to Gotham City and at some point never came back."

Bruce Sterling is an American novelist and journalist. A leader of the "cyberpunk" literary movement, he now writes and speaks on a wide range of subjects. In the story that appears in this issue *("The Interoperation," p. 69)*, an architect fights the creative limitations

imposed by computer automation. "I love to hang out with industrial designers, engineers, and architects—people whose business is creating the physical world," Sterling says. "Word processing transformed my line of work 30 years ago, but every year, design software eats up more of these guys' time-honored enterprises. I had to ask that classic science fiction question: what happens if this goes on?" Sterling is moving to Turin, Italy, which the International Council of Societies of Industrial Design has designated World Design Capital for 2008.

Greg Egan is an Australian science fiction writer and computer programmer; his new short story "Steve Fever" appears in this issue *(p. 60)*. "People often lament the way some politicians and celebrities end up believing their own public relations," says Egan. "I thought it would be interesting to imagine what might happen if we developed technology that was capable of believing its own hype." Egan recently completed his seventh novel, *Incandescence*, which he says "concerns an alien society with very simple technology struggling to understand general relativity, as a matter of life and death."

SONY

HDNA

Watch Peyton Manning the same way a network cameraman does. On a Sony.

Nearly every major sport is broadcast using Sony HD cameras. The Sony BRAVIA® HDTV uses our knowledge of high definition to bring the game into your home in Full HD. Not to mention, Sony MotionFlow™ technology for ultra-fast screen response, and a 10-bit display for the incredibly vibrant range of colors you'd expect from a Sony HDTV. Why would you watch sports on anything else? High Definition. It's in our DNA. **sony.com/hdna**

Full HD, MotionFlow technology, and 10 bit panel available on select BRAVIA models. Screen image simulated.

like.no.other™

Full HD 1080

Letters

Who Wants to Live Forever?

In "The Enthusiast" (September/October 2007), David Ewing Duncan discusses the scientific controversy surrounding Harvard biologist David Sinclair's longevity research but fails to mention a more sinister controversy, one that exists outside the scientific community. As a bioethicist, I am unhappily aware that many of my fellow bioethicists oppose in principle any attempt to extend the human life span. They think people should accept the "natural" limits on longevity, although they do not oppose electric power on the grounds that we should accept the "natural" limits on indoor light and warmth. As a future old person, I hope that scientists will continue to ignore such small-mindedness and that someday your magazine's feature on outstanding innovators in the early stages of their careers will feature innovators under 150 rather than just those under 35.

Felicia Nimue Ackerman
Providence, RI

Conservative British philosopher Roger Scruton is profoundly uneasy about the morality of seeking to live for hundreds of years, and he makes elegantly referenced arguments about why such a quest is a bad idea ("The Trouble with Knowledge," May/June 2007). However, his arguments overlook one simple fact: each new breakthrough will offer us not immortality but simply the opportunity to *not die today*. That is how longevity has been achieved over the last 100 years: each wave of miracle drugs has helped push the grim reaper back a few years. The by-product of medical progress is that one day, someone may wake up for his 1,000th birthday. If on that day pain lashes him and the world goes gray, he will cry out, "Please! Of course I do not want to live to be 2,000. Who would? But I do not want to die *today*!"

William Bains
Royston, Hertfordshire, England

On Chess

Philosopher Daniel C. Dennett reaches the verdict that computers are the equal of humans in chess ("Higher Games," September/October 2007). To the contrary, computers cannot play chess at all. Chess is a game; games are for having fun; computers cannot have fun.

Daniel Pratt
Laurel, MD

Bright Lights in Stockholm

I loved the 1962 photo that accompanied James Watson's essay recounting his part in the discovery of the structure of DNA ("Letter to a Young Scientist," September/October 2007). Six brilliant men posing side by side with their Nobel Prizes: five great scientists and ... John Steinbeck! I wonder who, as they sidled together for the picture, was more in awe of whom?

Larry Casey
Huntsville, AL

Alieu Conteh

I found inspiration in the most unlikely place this morning. I ran across your Q&A with African entrepreneur Alieu Conteh (September/October 2007), in which he recounts the fascinating tale of his successful attempt to build a mobile-communications network in war-torn Congo. What a remarkable story of vision, energy, and optimism. I've enjoyed a subscription to your publication for several years, but this is the first time I'm circulating an article not simply because it informed me about technology but because it moved me.

Bill Cooke
Dearborn Heights, MI

Patent Law

I was very pleased to see the magazine publish an accurate patent law article written by a patent attorney ("Patent Law Gets Saner," September/October 2007). Scott Feldmann provided an excellent lay summary of the impact, especially on patent "trolls," of three very important (and notably concurrent) United States Supreme Court patent cases: *eBay*, *MedImmune*, and *KSR*, which many patent attorneys (me among them) had been avidly following. The soundness of these decisions may be due in part to the unusually large number of *amicus* briefs that were filed by organizations and academics.

Paul F. Morgan
Rochester, NY

Artificial Intelligence

I enjoyed the thought-provoking essay by Yale computer scientist David Gelernter about the state of artificial intelligence ("Artificial Intelligence Is Lost in the Woods," July/August 2007). It *does* seem as if AI research is lost in its quest to emulate conscious thought. However, artificial life, a small offshoot of AI research, makes the subversive presumption that, as in nature, conscious behavior emerges from the bottom up: that is, it arises from the daily toils of simple systems evolving into complexity.

Two recent achievements come to mind: the entries in the DARPA Grand Challenge robotic road race and the twin Martian rovers. In both cases, the coupling of software with robotic sensors and mechanics seems to have achieved a close approximation of a prime component of intelligent systems: proactive self-preservation.

Even though imbuing conscious thought in computers is not on the radar screen of those in artificial-life research, there is a sense that it may be just beyond the edge of the screen.

Maurice Havelday
Morgan Hill, CA

How to contact us

E-mail letters@technologyreview.com
Write *Technology Review*, One Main Street, 7th Floor, Cambridge MA 02142
Fax 617-475-8043
Please include your address, telephone number, and e-mail address. Letters may be edited for both clarity and length.

Qwest's tailored solutions allow you to get the most out of your network.

Because every company is unique, Qwest offers a consultative approach with a full portfolio of business solutions. When your communications are optimized, business thrives. That's why 95% of Fortune 500® companies choose Qwest.

Get Qwest. Get Nimble. Call 1 888-658-5655 or visit qwest.com/business.

QWEST BUSINESS SOLUTIONS

Qwest Spirit of Service®

Oppenheimer's Ghost

Can we control the evolution and uses of technology?

In a 1965 documentary, *The Decision to Drop the Bomb,* J. Robert Oppenheimer, who had been the scientific director of the American effort to build an atomic bomb during World War II, described his emotions on witnessing the first nuclear detonation. He said, "We knew the world would not be the same. A few people laughed, a few people cried, most people were silent. I remembered the line from the Hindu scripture the Bhagavad Gita. Vishnu is trying to persuade the prince that he should do his duty and to impress him takes on his multiarmed form and says, 'Now, I am become Death, the destroyer of worlds.' I suppose we all thought that one way or another."

It is mesmerizing television. (You can watch the clip on atomicarchive.com.) Oppenheimer—pale, penitent, emaciated, and already elderly at 61—cannot face the camera. He looks down as he speaks. His manner is not tentative—he knows precisely which words he wishes to employ—but painfully subdued. He blinks, he looks away, and at one point he actually seems to wipe away a tear.

This legendary recollection, which today appears in every account of July 16, 1945, may have been theater. His brother Frank, who was at the Trinity test site that day, remembered that Oppenheimer said simply, "It worked." William Laurence, a *New York Times* reporter who interviewed Oppenheimer a few hours after the explosion, wrote in his 1959 history, *Men and Atoms: The Discovery, the Uses, and the Future of Atomic Energy,* that he would never forget the "shattering impact" of the quotation. But Laurence's initial account, published in the *Times* in September 1945, has no reference to the Bhagavad Gita. The earliest version of the story occurs in a profile of Oppenheimer published by *Time* magazine in late 1948.

It doesn't matter. Whether Oppenheimer invented the story of a sudden, vertiginous consciousness of mankind's new destructive powers or imagined years later that he had thought or said such a thing, the documentary shows a sincerely suffering human being.

Oppenheimer has become a secular saint because he opposed building an early version of the hydrogen bomb when he was chairman of the U.S. Atomic Energy Commission. That opposition led to his persecution by anticommunists and a public hearing to investigate his loyalty, after which his security clearance was permanently revoked because of what were called his "defects" of character. Since his death, biographies have represented him as a cultured leftist intellectual at odds with brutish right-wing militarists. But the physicist's attitude to the nuclear bomb—and to the capacity of technology to be used for both moral and immoral ends—was more complicated.

In 1965, Oppenheimer told the *New York Times Magazine,* "I never regretted, and do not regret now, having done my part of the job." But he also said to Harry Truman, "Mr. President, I feel I have blood on my hands." In truth, he appears to have felt both emotions at once. The nuclear bomb might never have been built without Oppenheimer's energetic leadership, and he fought hard to see it dropped on civilians at Nagasaki and Hiroshima; but he also thought that its use was mass murder. He justified his role on the grounds that the bomb was necessary to win the war and that it might be a deterrent to future wars, ushering in Immanuel Kant's era of perpetual peace.

More interesting, Oppenheimer believed that technology and science had their own imperatives, and that whatever *could* be discovered or done *would* be discovered and done. "It is a profound and necessary truth," he told a Canadian audience in 1962, "that the deep things in science are not found because they are useful; they are found because it was possible to find them." Because he believed that some country would build a nuclear bomb, he preferred that it be the United States, whose politics were imperfect but preferable to those of Nazi Germany or the Soviet Union. When he later opposed building a hydrogen bomb, he was not being inconsistent, nor was he awakening to pacifism late in the day; he opposed an early, infeasible proposal, but he later recanted when the physicist Edward Teller proposed a "technically sweet" design.

Oppenheimer was a fatalist about the evolution of technology and science, which goes some way to explaining his attraction to the deeply fatalistic Gita. Consistent with Vishnu's teaching to Prince Arjuna, Oppenheimer thought it our duty to perform, as best we can, the jobs that our historical moment allots us. (This aspect of his thinking has been described by the historian James Hijaya in an essay, "The *Gita* of J. Robert Oppenheimer.") He looked to humanity's most progressive institutions to restrain the malignant use of technology. Oppenheimer was asked to build a nuclear bomb, and he hoped reason would dictate that it be used twice, in a just war, and then never again.

Well, so far at least, his ghost must be less troubled than the disturbed figure who appeared in that old documentary. But history lasts a very long time. Write to me at jason.pontin@technologyreview.com. **Jason Pontin**

MARK OSTOW

Bose® QuietComfort® Acoustic Noise Cancelling® Headphones

Now you have a choice.

On-ear
QC™3 headphones

Around-ear
QC™2 headphones

Bose began researching noise reduction technology 29 years ago. Since then, we've been leading the industry in advancing the category we created.

QuietComfort® 3 headphones represent the latest achievement. They rest on your ears rather than surrounding them. And while they are smaller than our highly acclaimed QuietComfort 2 headphones, there is no compromise in noise reduction, sound quality or comfortable fit. So now you have a choice: QC™2 headphones for around-ear use, and QC™3 headphones if you prefer a smaller, on-ear alternative.

Fold-flat design for easy storage.

Hear the difference Bose® technology makes. You will notice a dramatic decrease in engine roar on an airplane. The cabin becomes more peaceful. Connect your CD player, MP3 player, or listen to the in-flight movie. You'll hear detail you may have never experienced while flying. But our customers tell us that they use these headphones at home or at the office, too. Although the noise reduction will be more subtle than it is on planes, you should notice distractions fading softly into the background.

Enjoy your music with our best-sounding headphones ever. As *Ultimate Mobility* magazine reports, Bose headphones "have been the gold standard for years." The audio is so lifelike, you may find yourself discovering subtleties in your music that you've never heard before.

Two styles to choose from. Choose QC3 headphones for an on-ear fit, or QC2 headphones for an around-ear fit. Both QC2 and QC3 headphones offer the same total (active plus passive) noise reduction and the same acclaimed audio performance. Your choice should be made on whether you prefer around-ear or on-ear headphones.

FREE shipping with your order.

Try them for 30 days, risk free. Both styles come with our 30-day Excitement Guarantee. Take advantage of **12 easy payments,** with no interest charges from Bose.* QuietComfort Acoustic Noise Cancelling® headphones, from Bose, the most respected name in sound.

To order or learn more about Bose headphones:

1-800-901-0256, ext. Q6134

www.Bose.com/QC

BOSE®
Better sound through research®

F O R T R A V E L • W O R K • H O M E

*Bose payment plan available on orders of $299-$1500 paid by major credit card. Additional financing offers may be available for select products. See website for details. Down payment is 1/12 the product price plus applicable tax and shipping charges. Then, your credit card will be billed for 11 equal monthly installments with 0% APR and no interest charges from Bose. Credit card rules and interest may apply. U.S. residents only. Limit one active financing program per customer. ©2007 Bose Corporation. Patent rights issued and/or pending. Financing and free shipping offer not to be combined with other offers or applied to previous purchases, and subject to change without notice. Risk free refers to 30-day trial only and does not include return shipping. Delivery is subject to product availability. Quote reprinted with permission: *Ultimate Mobility*, Fall/03.

Only Kentucky matches federal SBIR-STTR Phase 1 + Phase 2 awards

Kentucky will match both Phase 1 and Phase 2 federal SBIR and STTR awards to our high-tech small businesses – no other state has a program designed to do just that.

If you are looking for a place to locate or start a high-tech company, Kentucky's SBIR-STTR Matching Funds program is just one of many reasons to give our state a look.

We are now accepting applications from companies in Kentucky (or willing to relocate to Kentucky) for state funds to match federal Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) grants. Phase 1 awards are matched up to $100,000 and Phase 2 awards up to $500,000 per year for two years.

Kentucky offers a wide range of support for high-tech small businesses, including grants, tax incentives, and other forms of early-stage funding. Our statewide network of Innovation and Commercialization Centers can offer business management and entrepreneurial training, while helping find financing.

The Cabinet for Economic Development can make growing a business in Kentucky fast and easy. Our low cost of living, low-stress commutes, and high quality of life amid unrivaled natural beauty are why Kentucky communities are rated among the best places to start a business and raise a family.

For more information about our SBIR-STTR Matching Funds and other business support programs, visit www.ThinkKentucky.com/dci/sbir1.

Kentucky UNBRIDLED SPIRIT

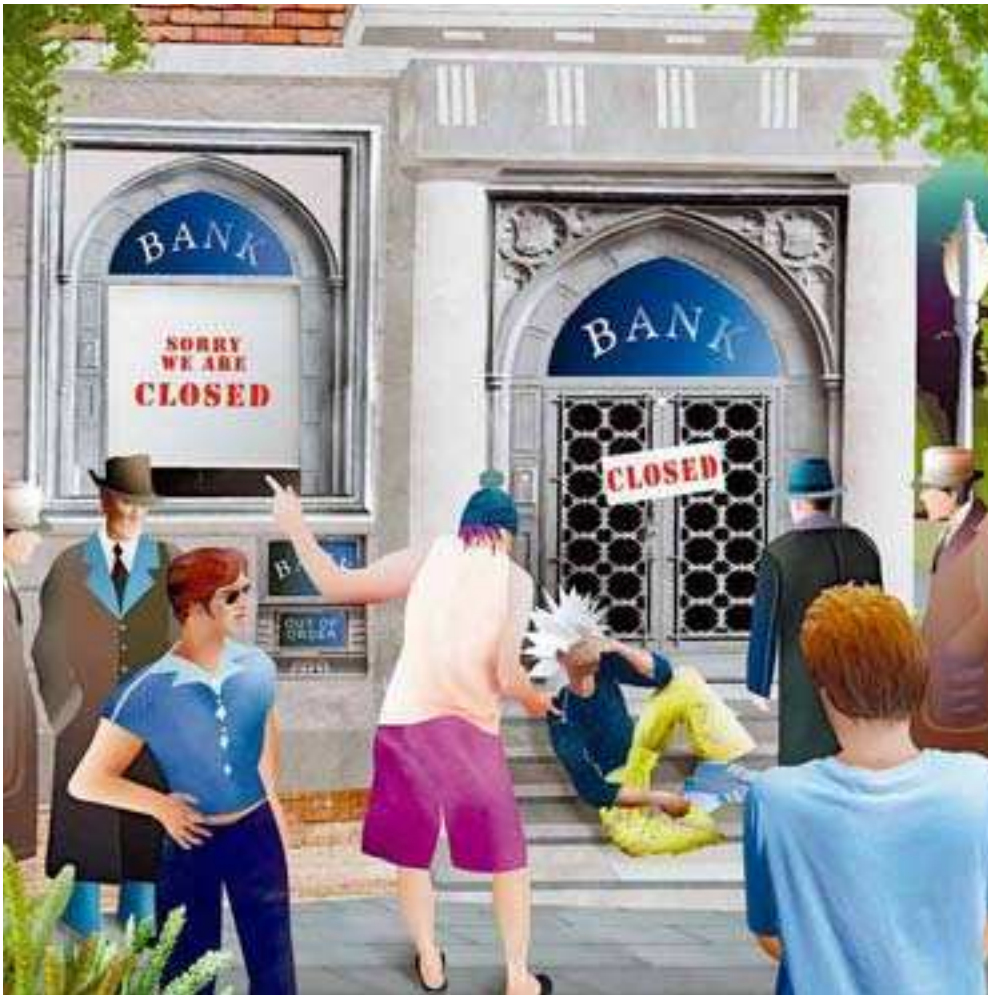
Cabinet for Economic Development

For more information about the SBIR-STTR program in Kentucky, call 1-800-626-2930 or visit www.ThinkKentucky.com/dci/sbir1.

Forward

INTERNET

Financial Woes in Second Life

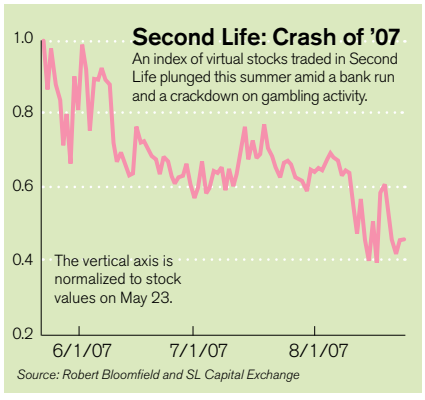


DEREK BACON

With more than nine million registered "residents," Second Life leads the boom in virtual worlds—online communities with their own computer-rendered topographies *(see "Second Earth," July/August 2007)*. But the rapidly growing community is facing a virtual monetary crisis that raises questions about its approach to handling real money.

Trouble started this summer when Second Life's parent company, Linden Lab, eliminated gambling activities, erasing about 5 percent of the virtual world's economy. Later, a bank run triggered the collapse of a bank, Ginko Financial, that offered high interest rates on virtual dollars convertible to real ones (Second Life's "Linden dollars" trade against the U.S. dollar at 270 to 1). "Most of these problems have been building for a while," says Benjamin Duranske, an intellectual-property lawyer who has been watching the Second Life banking industry.

So far, the virtual mess hasn't been monitored by real-world authorities such as the U.S. Securities and Exchange Commission, says Cornell University accounting professor Robert Bloomfield. But Second Life residents, partly because they'd like to forestall such monitoring, are forming their own virtual exchange commission to establish standards. And Linden Lab's chief financial officer, John Zdanowski, says the company is working to keep the currency exchange rate stable.



For now, financial instability in Second Life affects only the 45,000 people who actually make money there. But clearly, Linden Lab wants to make sure people don't get burned so badly that they log off and start focusing on their real lives. **Erica Naone**

MEDICAL DEVICES

Hidden Hearing Aid

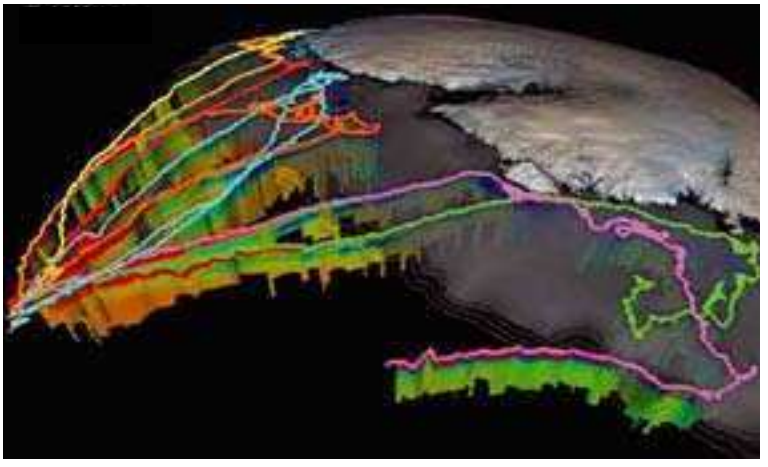
An implantable hearing aid *(above)* aims to overcome the drawbacks of traditional hearing aids—they're inconvenient, they're unsightly, and they're not supposed to get wet. The device, being developed by Otologics of Boulder, CO, uses a microphone implanted underneath the skin to pick up sound.

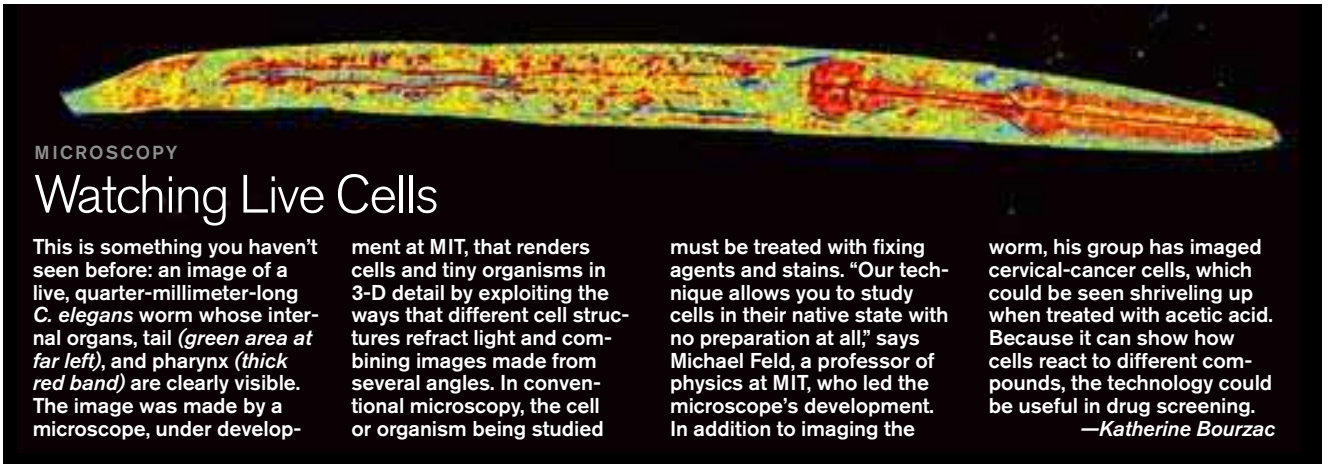
The signal from the microphone is processed and sent to a vibrating piston implanted against small bones of the middle ear, which transmit the vibrations to the inner ear. The user recharges the device's battery by placing a small radio transmitter against his or her head. In an early clinical trial, subjects using the device did not hear quite as well as they did with traditional hearing aids. The question is whether patients will see reduced performance—as well as the higher cost and surgical risk—as a tolerable price to pay for convenience and cosmetic benefits. *—Michael Chorost*

GLOBAL WARMING

Seals as Sensors

Sea mammals could be severely affected by climate change. Now some of these creatures are helping scientists figure out the complex dynamics of global warming. The tracks in the image below represent data collected by sensors glued to the heads of elephant seals swimming near the coast of Antarctica. As part of a three-year project, the sensors transmitted information about changes in ocean temperature and salinity that are crucial to explaining global climate change. Researchers from an international team wired the seals up and then released them; each time the seals dived—as many as 60 times a day, as deep as 600 meters—the sensors collected data. In the image, colored lines represent the routes of specific seals, and the shaded areas represent temperature readings when they dived. When the seals resurfaced, the data was sent by satellite and Internet to the Sea Mammal Research Unit in St. Andrews, Scotland, and then to the National Oceanographic Data Center in the U.S. and the Coriolis center in France, where oceanographers relayed it to climate researchers. When the seals molted, they shed the equipment. **Michael Patrick Gibson**



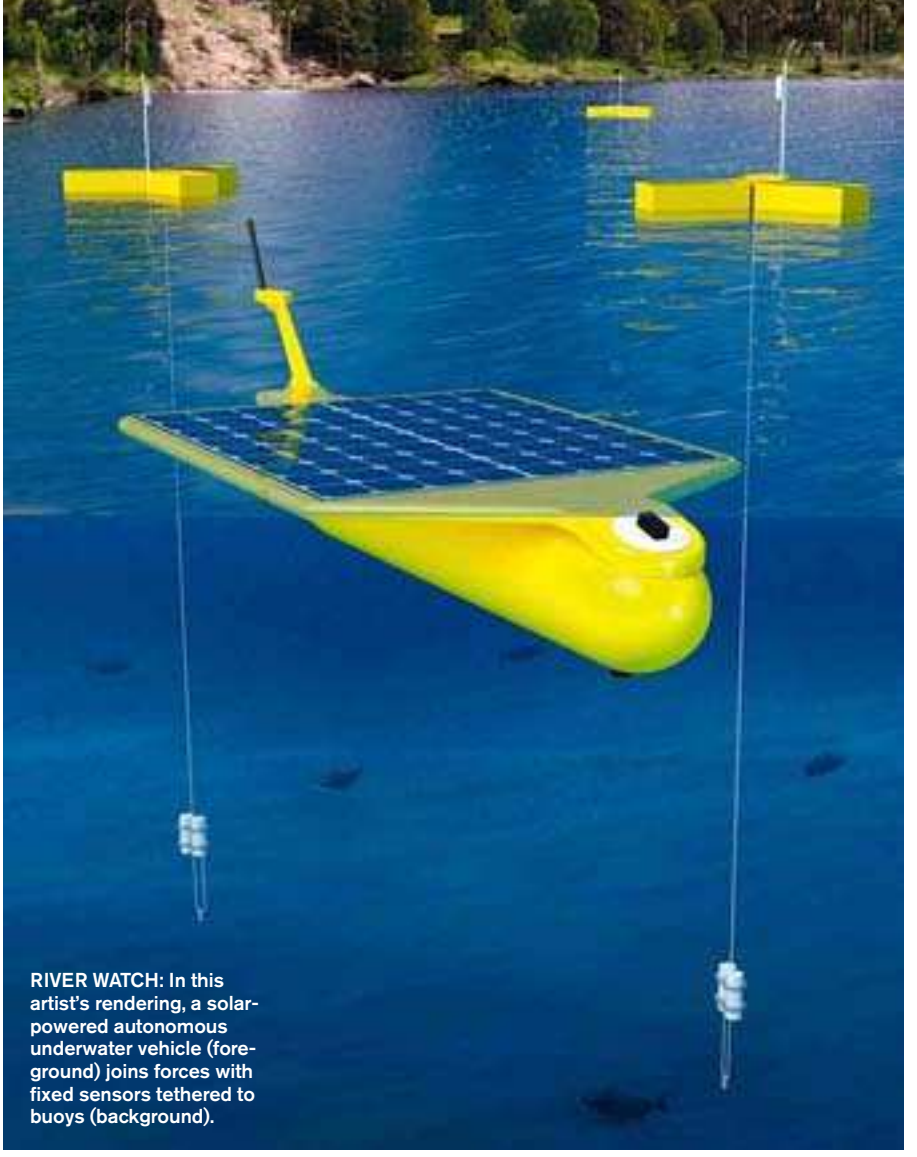


MICROSCOPY

Watching Live Cells

This is something you haven't seen before: an image of a live, quarter-millimeter-long *C. elegans* worm whose internal organs, tail *(green area at far left)*, and pharynx *(thick red band)* are clearly visible. The image was made by a microscope, under development at MIT, that renders cells and tiny organisms in 3-D detail by exploiting the ways that different cell structures refract light and combining images made from several angles. In conventional microscopy, the cell or organism being studied must be treated with fixing agents and stains. "Our technique allows you to study cells in their native state with no preparation at all," says Michael Feld, a professor of physics at MIT, who led the microscope's development. In addition to imaging the worm, his group has imaged cervical-cancer cells, which could be seen shriveling up when treated with acetic acid. Because it can show how cells react to different compounds, the technology could be useful in drug screening. *—Katherine Bourzac*

COURTESY OF OTOLOGICS (HEARING); SEA MAMMAL RESEARCH UNIT (SEALS); MICHAEL FELD LABORATORY, MIT (CELLS)



RIVER WATCH: In this artist's rendering, a solar-powered autonomous underwater vehicle (foreground) joins forces with fixed sensors tethered to buoys (background).

ENVIRONMENTAL MONITORING

Networking the Hudson

A research consortium that includes the Beacon Institute, IBM, and Rensselaer Polytechnic Institute plans to distribute hundreds of sensors throughout the Hudson River. By collecting information on everything from salinity and temperature to oxygen levels and the presence of fish schools, the sensors will help create a "virtual river" that can aid scientists monitoring aquatic life and pollution levels.

Some sensors are likely to be mounted on a novel, solar-powered underwater robot developed by RPI, the Autonomous Undersea Systems Institute in Lee, NH, and Falmouth Scientific in Cataumet, MA. Other sensors will be fixed to buoys and suspended at various depths. In some cases, fiber-optic cables will convey data to the surface, where it will be sent ashore wirelessly. "This project is without a doubt a huge advancement [in sensor networks] and is on a much larger scale than anything that has been done before," says Sandra Nierzwicki-Bauer, a freshwater biologist at RPI and a leader of the effort.

Because of its scale, the network will demand a massive new data-analysis system, which IBM will provide. One goal is rapid response to changing conditions, such as a sewage release or a drop in oxygen that could kill fish. Completing the design will take more than a year, but the first sensors will be placed in the river in early 2008. The full installation is expected to take three years. **Brittany Sauser**

JOHN MACNEILL (HUDSON); PATRICK BAUDISCH (SCREEN)

HARDWARE

A Better Touch Screen

As touch screens shrink, one of the biggest problems users face is that their fingers cover up what they're trying to look at. An experimental setup from researchers at Microsoft and Mitsubishi lets people essentially touch their screens from the back. A semitransparent image of their fingers is superimposed on the front of the display.

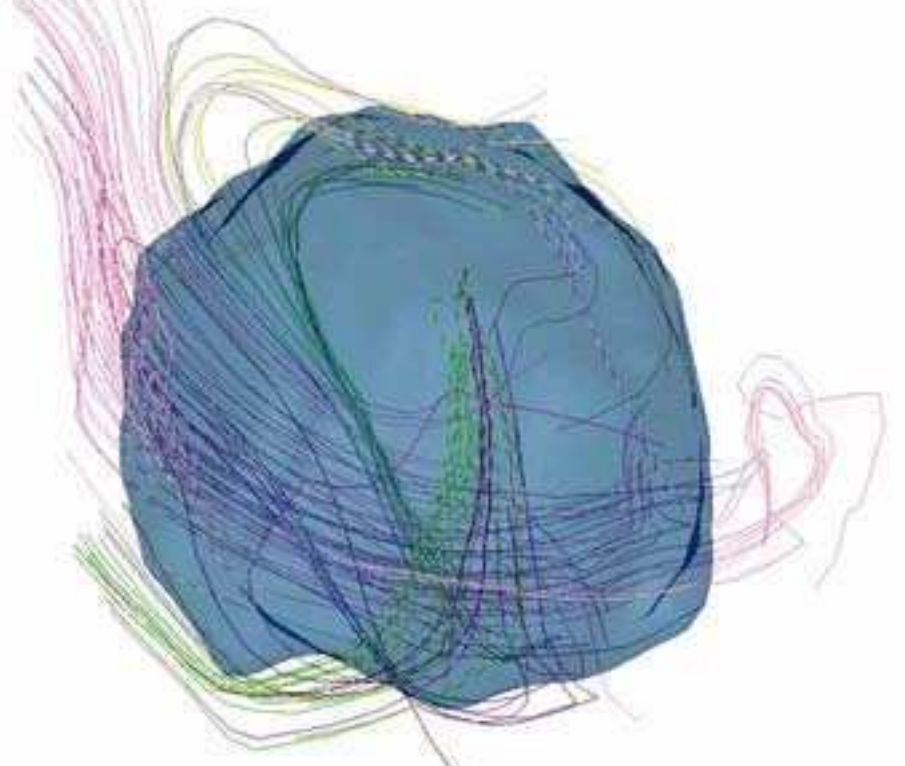
To build their prototype, the researchers glued a touch pad to the back of a conventional touch-

screen device; then they added a Web camera that captures an image of the user's hand. Software creates the semitransparent representation of the hand, correlating its position with that of the real hand. Having built an experimental but admittedly impractical version of the device, the researchers are now exploring versions (like the one in the artist's rendering above) that could be commercially viable. One approach involves a touch pad with an array of capacitors whose electrical charge is altered by the proximity of the user's fingers. In another, arrays of single-pixel light sensors would map the fingers' location. ***—Kate Greene***

EMERGENCY RESPONSE

Watching Wildfires

Fighting a wildfire requires knowing exactly how it is moving and where hot spots are flaring. The image above—of a fire that burned parts of Santa Barbara County, CA, earlier this year—was produced by an experimental system that uses remote sensors to provide just such information to emergency responders, rapidly reporting changing conditions. The image was captured by a 118-kilogram infrared scanner in an unmanned airplane. Images were processed onboard, sent via satellite to a ground station, fused with geographic-information-system data, and displayed using Google Earth—all within minutes. Areas of the greatest heat intensity show up as the brightest spots on the image. Once tests are completed next year, the U.S. Forest Service may install the sensor-and-communication system in manned aircraft. ***—Brittany Sauser***



MEDICAL IMAGING

3-D View of the Brain

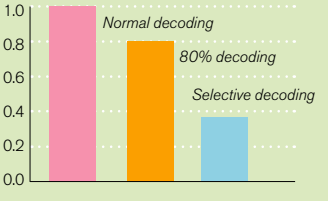
This 3-D rendering of a brain tumor and associated brain fibers, made by researchers at Thomas Jefferson University in Philadelphia, is the product of new software that integrates data from multiple imaging technologies to provide much clearer images. The image shows a tumor *(blue mass)* and its position relative to brain fibers *(threadlike objects)* that are affected by the tumor and vital to brain function. The software lets surgeons see which fibers are engulfed by the tumor *(dashed lines)* and which are outside the tumor *(solid lines)*. Colors indicate the depth of the engulfed fibers or the exterior fibers' distance from the tumor's surface; for example, pink and red dashed lines represent deeply engulfed fibers. Pilot studies have demonstrated the software's usefulness in neurosurgical planning; the researchers expect that with fine-tuning, the technology could be in operating rooms within a year. The images use data from conventional magnetic resonance imaging (MRI), which gives details on anatomy; functional MRI, which provides information on neural activity; and diffusion tensor imaging, which provides images of fibers connecting different brain areas. **Brittany Sauser**

GADGETS

Battery Booster

Voice transmission and video playback are the biggest power hogs in mobile devices, but skipping some signal-processing tasks could greatly boost battery life without a huge sacrifice in quality. Media files must be decoded during playback, and if a device decoded only 80 percent of the information, it would use only 80 percent as much power. A new technique could cut power consumption even more, says Gang Qu, a computer scientist at the University of Maryland. Peculiarities in coding mean that the processing time—and power—required to decode a block of information varies. Qu and colleagues wrote an algorithm that imposes strict time limits on the decoding process; the decoder skips only the jobs that take too long. In simulations, this approach yielded an 81 percent completion rate but used only 37 percent as much power as decoding everything. Qu says blocks of information requiring longer decoding time may not always be more critical than the rest. *—Larry Hardesty*

Power Consumption



NASA (WILDFIRE); XIN GUAN (BRAIN)

GLACIOLOGY

Postglacial Rebound

EARTH MONITOR: A one-meter-tall GPS station sunk in bedrock near Ilulissat, Greenland, detects how the earth's crust moves as the island's massive ice sheet slides and melts.

The effort to determine how fast the ice sheets that blanket Greenland and Antarctica are melting is complicated by something called "postglacial rebound." As the earth's crust is relieved of its millennia-long burden of ice, it recovers its original shape. The rebound of the bedrock underlying the ice can confuse measurements of the ice's thickness and mass.

To correct for this, a team of scientists from the U.S., Denmark, and Luxembourg installed 24 continuous GPS stations in bedrock around the coast of Greenland this summer. At year's end, they'll head for Antarctica to install 16 more. The project involves researchers from Ohio State University and engineers from Unavco of Boulder, CO. The stations, powered by solar panels and large battery packs, can measure lateral and vertical shifts of the earth's crust down to the millimeter scale. Equally important, they continuously beam out their readings. The data they generate should allow other sensors—which monitor elevation changes, glacial outflow rates, and the overall mass of the great ice sheets—to measure the rate of ice loss with greater accuracy. *—David Talbot*

DISPLAYS

Better than High-Def

Today's high-definition displays pack in the pixels to provide breathtaking color and detail. But another display technology, called high dynamic range (HDR), can produce far higher contrast, correctly and vividly displaying details of both the brightest and darkest areas within the same scene.

HDR products might be available soon; earlier this year, Dolby bought HDR-display maker BrightSide Technologies, of British Columbia. The company's liquid-crystal-display prototypes are illuminated by arrays of tiny light-emitting diodes (LEDs); individual LEDs can be controlled, increasing the darkness or brightness of various parts of an image.

Just as high-def-display makers initially faced sluggish sales because most TV content wasn't filmed in high definition, wasting their displays' extra capacity, HDR-display makers have to contend with TV content that doesn't capture high-contrast information.

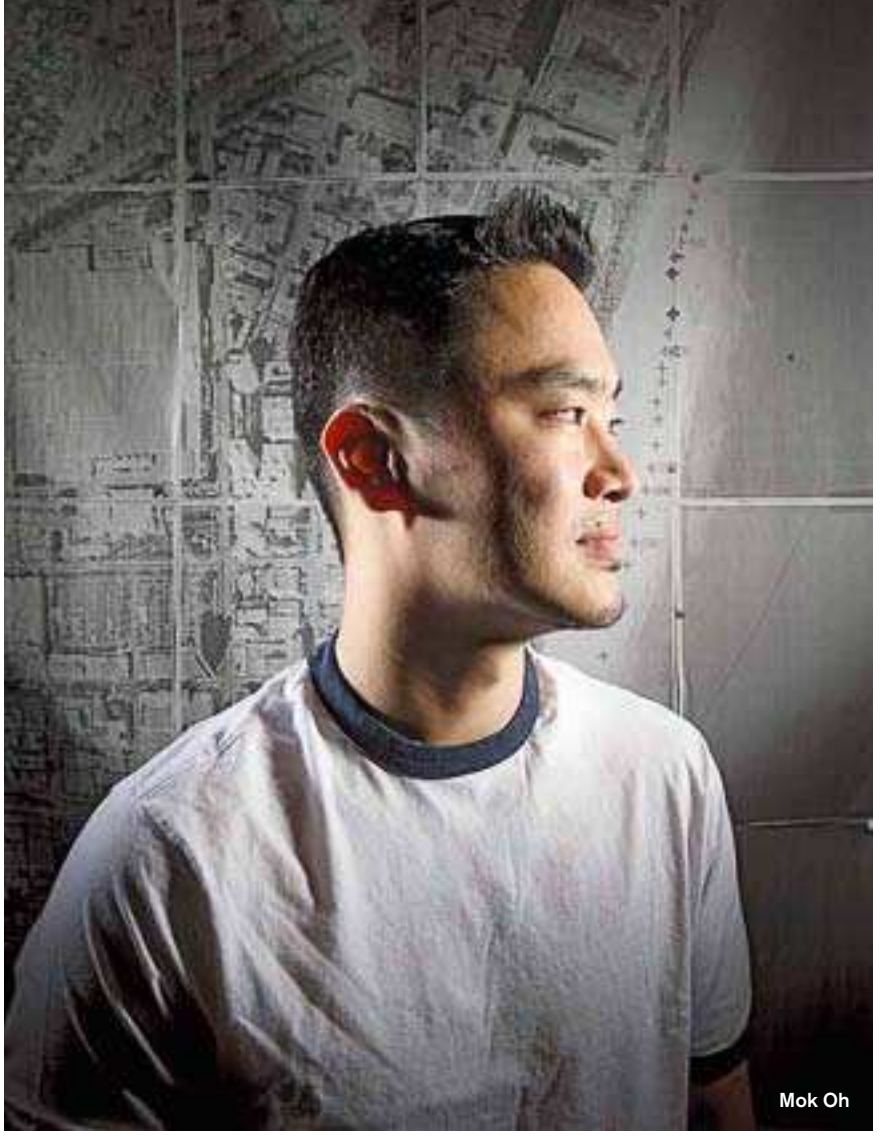
But Ahmet Oguz Akyüz, Roland Fleming, and colleagues at the Max Planck Institute for Biological Cybernetics in Tübingen, Germany, have good news. They conducted perceptual experiments to show that when ordinary images are displayed on an HDR screen, simply enhancing their contrast—increasing the intensity of the brights and diminishing the intensity of the darks—mimics the HDR effect and produces pleasing results.

So even if your favorite show isn't filmed to capture high contrast, you could soon be seeing it in a whole new light.

Kate Greene

STUDY IN CONTRAST: A high-dynamic-range display renders bright and dark regions of the same image with great clarity. An image of a castle (bottom) simulates the improvement over what is possible with a conventional display (top).

ERIK REINHARD (HIGH-DEF); THOMAS NYLEN, UNAVCO (REBOUND)



Mok Oh

STARTUP

Virtual Streetscapes

Picking up where Google Earth leaves off, EveryScape depicts streets and building interiors with photorealistic detail

With Google Earth, users can "fly" from a satellite view of the planet to aerial views of their homes. But while the program can be customized to include, say, photos of storefronts or 3-D renderings of buildings, it provides no consistent experience at street level.

EveryScape, a startup in Waltham, MA, hopes to pick up where Google Earth leaves off, providing photorealistic streetscapes and even views inside buildings. The company plans to let users submit photos that it will integrate into a consistent 3-D representation. Its revenues would come from retailers who want to add depictions of their stores' interiors. CTO and founder Mok Oh, a computer scientist, says the company is betting that people want to explore the world from the ground level. "Getting there is not what you want," he says. "Being there is what you want."

The technology starts with panoramic photos taken by company photographers or contributed by subscribers, who use conventional digital single-lens reflex cameras. EveryScape's servers construct a 3-D environment that allows users to move from one panoramic perspective to the next. In a company demo, users can explore Union Square in San Francisco, enter Harry Denton's Starlight Room, move through the lounge viewing it from different perspectives, and exit again for a dizzying look at the night sky above the Dewey Monument. Oh had already founded a business that used an earlier version of the technology to enable vivid virtual tours of high-end hotels and travel destinations. He now envisions expanding the idea to virtually reproduce the entire world.

Derek Hoiem, a researcher at the University of Illinois at Urbana-Champaign, finds EveryScape's technology promising. He says it would be better with more freedom of movement—if the user could walk down a virtual street rather than swiveling to explore a panorama and then moving forward a fixed distance to the next panorama. But he adds that the software gives users a good approximation of motion, and that they will find its immersive quality appealing.

EveryScape launched this fall, depicting parts of Aspen, Boston, Miami, and New York. Retail stores that pay for inclusion will be graphically rendered; users will enter the virtual stores, view merchandise, and click links to get to the stores' Web pages. CEO Jim Schoonmaker says EveryScape plans to add more features, such as the ability to buy merchandise inside a store by clicking on a display item. EveryScape is likely to face competition from Google *(see "Second Earth," July/August 2007)*, but the search giant wouldn't comment on its plans. **Erica Naone**

Company: EveryScape, Waltham, MA
Funding: $5 million from Draper Fisher Jurvetson, New Atlantic Ventures, and Launchpad
Technology: Software to fuse panoramic photos into virtual streetscapes
Founder and CTO: Mok Oh, computer scientist and founder of SuperTour, which provides virtual tours
CEO: Jim Schoonmaker

CHRISTIAN KOZOWYK

ONE NATURAL RESOURCE IN ONTARIO IS MINED MORE THAN ANY OTHER.

Innovative industries have been unearthing talent in Ontario for decades, and have polished it into the most highly skilled workforce in the G8. It's also the most knowledgeable; with 56% having a post-secondary education, the highest rate of any industrialized nation. In fact, the 2005 World Competitiveness Yearbook ranks our education system ahead of Japan and the U.S. in its ability to meet the needs of a competitive economy. And competitive we are, in fields as diverse as IT and communications, aerospace, and biotechnology. Brainpower is a renewable resource, too, as Ontario's 44 universities and colleges produce a steady supply of graduates every year in mathematics, engineering and sciences. Put Ontario's minds to work for you. There's no better place in the world to do business.

ONTARIO
CANADA

2ontario.com/talent
1-800-819-8701

Ontario Paid for by the Government of Ontario.

Google Earth

How Google maps the world

By Simson Garfinkel

Type "77 Massachusetts Avenue 02139" into Google Earth, and you'll see MIT's Great Dome in all its glory. Click a button to zoom out, and soon you'll see the state capitol, the celebrated Zakim Bridge, and maybe some other college up the river. These images, which are shared by Google Maps, are actually a combination of aerial photos and satellite imagery—and a lot of post-processing. *Technology Review* interviewed engineers at Google and at DigitalGlobe, the company that supplies Google's satellite photos, and did a little bit of reverse-engineering to figure out how it works.

1 High-Resolution Imagery

As it passes overhead at an altitude of 450 kilometers, DigitalGlobe's QuickBird satellite photographs the planet's surface. The satellite can take "snapshots" roughly 16.5 kilometers square or record "strips," which measure 16.5 by 330 kilometers. The average resolution is roughly 60 square centimeters per pixel if the satellite is looking straight down, or less if it is looking at an angle. But because the satellite makes only 15 orbits per day, and because there is huge competition for its camera, most regions of the planet have not been photographed at high resolution. (Just try looking at Hazelton, WV, in Google Earth.) Lower-resolution data is provided by other satellites, like the Landsat-7, which has imaged the entire planet at a resolution of 15 meters. Information about an image's absolute position is captured with the help of GPS.

5 www.google.com/maps

Running inside a Web browser, the Google Maps client application contains more than 200 kilobytes of compact and obfuscated JavaScript that is downloaded when the browser first displays the map. The application determines which piece of which pyramid should be displayed next and requests it using a standard HTTP "get" command—the same command that's used to download Web pages and images from any Web server. The images are stored in the browser's cache and displayed when the user scrolls to the requested area, zooms in, or zooms out. The browser automatically throws away images from the cache when they are no longer needed.

2 Ground Station and Postprocessing

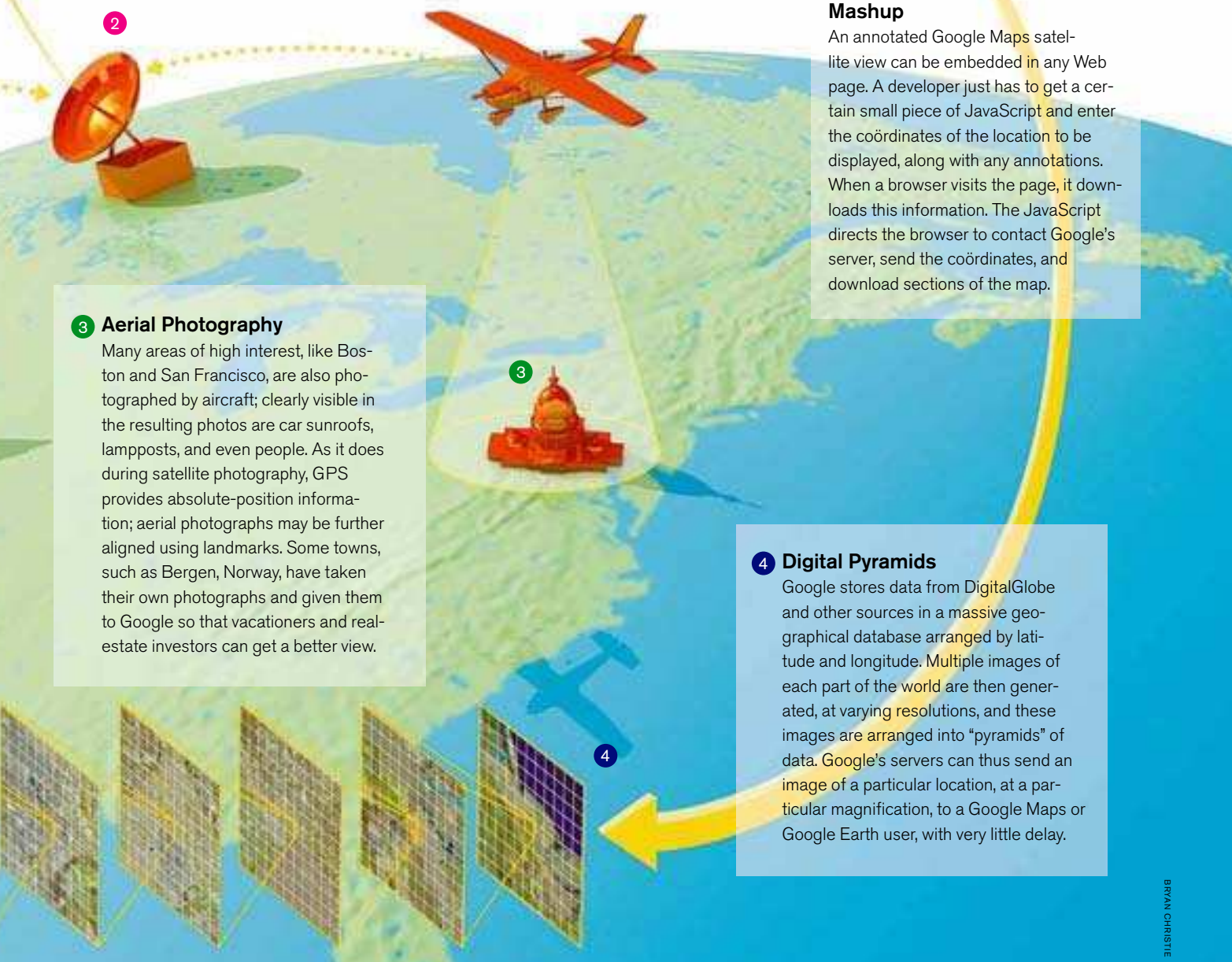
The satellite stores the image, then sends it down to DigitalGlobe's ground station in either Norway or Alaska when it passes overhead. The data then travels to a data center in Colorado, where differences in photographic angle are corrected, and the images are mapped onto a 3-D digital elevation model. This process, called orthorectification, prevents features on the tops of hills and mountains from being smeared out or placed in the wrong locations. Finally, the image is resampled so that its pixels will be aligned with the latitude-longitude grid. (The digital elevation model is what lets Google Earth "tilt" the ground for realistic views of the Grand Canyon and Mount Everest.)

Annotation

Respected information providers like *National Geographic* and Google community members like your Aunt Betty can supply additional "layers" of data that are tied to particular geographical locations. That information is also stored on servers at Google and elsewhere on the Internet. The list of all available layers appears at the lower left of the Google Earth application window; checking a box makes the application ask the servers for all the layer data for the geographical area that's on the screen and superimpose the data on the landscape.

Mashup

An annotated Google Maps satellite view can be embedded in any Web page. A developer just has to get a certain small piece of JavaScript and enter the coördinates of the location to be displayed, along with any annotations. When a browser visits the page, it downloads this information. The JavaScript directs the browser to contact Google's server, send the coördinates, and download sections of the map.



3 Aerial Photography

Many areas of high interest, like Boston and San Francisco, are also photographed by aircraft; clearly visible in the resulting photos are car sunroofs, lampposts, and even people. As it does during satellite photography, GPS provides absolute-position information; aerial photographs may be further aligned using landmarks. Some towns, such as Bergen, Norway, have taken their own photographs and given them to Google so that vacationers and real-estate investors can get a better view.

4 Digital Pyramids

Google stores data from DigitalGlobe and other sources in a massive geographical database arranged by latitude and longitude. Multiple images of each part of the world are then generated, at varying resolutions, and these images are arranged into "pyramids" of data. Google's servers can thus send an image of a particular location, at a particular magnification, to a Google Maps or Google Earth user, with very little delay.

BRYAN CHRISTIE

William Hurlbut

Embryonic stem cells without embryos

William Hurlbut, a physician and ethicist, is best known as a member of the President's Council on Bioethics. Though he has spoken out against the destruction of embryos for research purposes, he is nonetheless a supporter of embryonic-stem-cell research. He avoids what would otherwise be a terminal paradox through a proposal that he calls "altered nuclear transfer," or ANT. His goal: to create embryonic stem cells without destroying human embryos.

One of the most promising methods for creating embryonic stem cells is cloning: the nucleus of an egg cell is replaced by the nucleus of an adult cell, a process called somatic-cell nuclear transfer. The egg is then induced to divide, and the stem cells harvested from the resulting embryo are pluripotent, meaning they can form any sort of tissue in the body. But harvesting the stem cells destroys the embryo. By contrast, ANT (which has been shown to work in mice, if not humans) switches off vital genes—through alteration of the somatic-cell nucleus, the cytoplasm of the egg, or both—before the transfer takes place. Hurlbut says the resulting cell mass could not become an embryo but could produce pluripotent stem cells.

Hurlbut recently spoke with Michael Fitzgerald about ANT.

***TR*: What compelled you to come up with altered nuclear transfer?**

Hurlbut: When the President's Council met [to debate the ethics of stem-cell research, in 2002], it was clear that both sides of this debate are promoting important positive goods: that on the one hand you have people trying to defend human dignity from its earliest stages, and on the other hand you have people trying to promote advances in science and medicine. And as I sat there and listened to this debate, I thought, "Isn't there an answer to this? Isn't there some third option, some way that both of these goals can be achieved?"

I thought of dermoid cysts, benign ovarian tumors that produce all the cell types, tissues, and partial organs of the human body. Clearly something like embryonic stem cells is being produced in those tumors. And I thought to myself, "If nature can do this, we can do it. There must be simple technological alterations we could use in concert with nuclear transfer such that we produced embryonic-type, pluripotent stem cells, but without producing the unitary organism that is a human embryo."

Does ANT produce truly pluripotent stem cells?

[MIT's] Rudy Jaenisch got pluripotent cells. He injected some of the cells into living mice, and they formed tumors with all the tissue types in them. So yes, it works. The next step with altered nuclear transfer is to study it in primates. If it works in primates, specifically in rhesus macaques, then we can proceed with pretty good confidence, but also caution, in working with human cells.

How does mutating an embryo so it is no longer a viable embryo really solve the problem?

That is exactly the wrong way to frame the description of what's being done. The idea that we're mutating an embryo is an inaccurate and misleading representation of what we're doing. The key to the project is that no embryo is ever created. It's not a deficiency in an embryo but an insufficiency in the starting component, such that it cannot rise to the level of a living being.

Shinya Yamanaka and others are having success reprogramming adult skin cells into embryonic stem cells. Why should we continue with ANT?

Yamanaka's cells are very, very interesting and may solve the issue of how to procure embryonic-type stem cells. But altered nuclear transfer takes things back to the very beginning, to the single-cell stage. So ANT would give us the ethical framework and technological tools for probing early development, without the creation and destruction of human embryos.

Are there circumstances that you could imagine under which you might condone embryonic-stem-cell research?

I'm in no sense an opponent of research with embryonic stem cells as such. I have moral concerns about how the stem cells are obtained, not about the use of the cells themselves. I'm not in favor of the destruction of human embryos for research purposes.

What are the ethical and moral issues we face in neuroscience?

One of the most fundamental questions is how you correlate the neurological development during embryogenesis with moral standing. Some people argue that until you have a conscious being, or maybe a self-conscious being, you don't have moral value. We don't know exactly what consciousness is, but most neurophysiologists don't think there's consciousness present before 18 or 20 weeks at the earliest. If that's your criterion, you could probably justify the instrumental use of human embryos up to maybe 20 weeks. So without a strong moral principle, you may very well see the argument over stem-cell research move from 14 days to later stages. So at least at the federal-funding level, we should preserve the principle of the defense of human life from its earliest origins in the one-cell stage. TR

ANDREW NAGATA

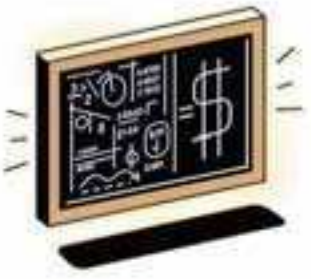
FINANCE

On Quants

Daniel W. Stroock argues against blaming them for market turmoil.

The role that so-called quants play in the financial world is analogous to the role batfish play in keeping coral reefs tidy. Just as batfish do not construct the reef but are essential to its health, quants do not create the structure financial markets depend on but do preserve the conditions that make markets function. So it would be misleading to suggest that quants were responsible for this summer's meltdown in the subprime-mortgage market or for the broader troubles that followed *(see "The Blow-Up," p. 36)*.

The functioning of financial markets relies on the general acceptance of certain assumptions. One of the most important is that the market will not sustain an opportunity for someone to have a free lunch. That is, although arbitrage opportunities will arise, market forces will eliminate them. As Fischer Black and Myron Scholes demonstrated in 1973 with their seminal model for determining the value of a stock option, the "no arbitrage" assumption provides individuals with a rational basis for putting a fair price on a variety of financial instruments. Thus, it is essential that the assumption be correct, and an important role of the quant is to make sure that it is. By scrutinizing financial data, quants spot arbitrage opportunities and alert their employers to act before others have a chance to do the same.



Another basic assumption is that risk is necessary and even beneficial. On the other hand, investors are willing to incur risk only if it's spread out. Insurance is the classic example of a mechanism for spreading the risk of financial disaster, but recently, investment companies have introduced much more sophisticated mechanisms. They make the risk palatable by embedding it in attractive-looking financial instruments in which it is diluted, and what remains of it is less evident. Such instruments are called derivatives, and with the help of inventive quants, the derivatives market has come to resemble a dim sum platter of enticing morsels. A further similarity is that overindulgence can cause indigestion.

Although I have had students who later thrived on Wall Street, I consider the role they play there closer to that of the sweepers who used to clear the ticker tape off the floor of the stock exchange than to that of a traditional investment banker. Most of the time, they have no idea what, if anything, is made by the companies with whose stocks they deal. Their mission is to blindly keep those stocks moving, not to pass judgment on their value, either to the buyer or to society. Thus, I find it completely appropriate that quants now prefer the euphemism "financial engineer." They are certainly not "financial architects." Nor are they responsible for the mess in which the financial world finds itself. Quants may have greased the rails, but others were supposed to man the brakes. TR

Daniel W. Stroock is a professor of mathematics at MIT.

SOCIAL COMPUTING

Friend Spam

Friendster founder **Jonathan Abrams** looks at his revolution.

Five years ago, I imagined a website that would show how people were connected to each other in real life, so I built a prototype called Friendster. I decided that one of its central features would be a friend confirmation process. When you wanted to add someone as your friend, an e-mail notification was sent with your request. If—and only if—the person approved your request, you were both listed as each other's friends. Five years later, I am paying the price for this innovation as I face an avalanche of friend spam. I get several friend requests per day from Friendster, MySpace, and Facebook, and also from social-media services such as Yelp, Flickr, and Pownce.

What is Pownce, you ask? Let's take a step back. The "microblogging" site Twitter was launched in 2006 by Blogger cofounder Evan Williams to help people update their friends via phone or Web with short messages about their current whereabouts or thoughts *(see "What Is He Doing?" p. 44)*. Twitter was all the rage at March's South by Southwest Interactive Festival, seemingly supplanting a predecessor called Dodgeball, but by May, überblog Techcrunch had proclaimed that people were already "making the switch from Twitter to Jaiku."

I never even got a chance to try Jaiku before Pownce launched in late June. Pownce was billed as a file-sharing service but looked a lot like Twitter. Still not open to the general public, it has received tremendous hype thanks to its association with the cofounder of Digg. (For a review of the microblogging phenomenon, see "Trivial Pursuits," p. 80.)

The press, bloggers, and the investment community are excitedly following every shift in buzz, from Dodgeball to Twitter to Pownce, or from Friendster to MySpace to Facebook. Since the launch of the Facebook Platform in May, the press and many so-called experts have finally begun recognizing the value of Facebook's "social graph"—the map of connections between real friends. But

HARRY CAMPBELL

ironically, as the tech elite have begun to deride MySpace's seizure-inducing page designs and promiscuous friend seekers, Facebook's clean user interface and focus on real friends faces an onslaught of new users and pointless applications where tattooed zombies buy drinks for your top friends.

However this all plays out, it's clear that these sites are not going to go away. In 2004, VCs bemoaned any further investment in social-networking companies, and pundits argued that social-networking sites would not endure as stand-alone destinations. Today, they are some of the biggest sites on the Web, and we have an entire industry of widget and tool providers building on top of the social-networking ecosystem. There are niche social-networking sites for moms, dogs, pagans, and bodybuilders. Ten years ago I moved to Silicon Valley to work at Netscape. Today, Netscape cofounder Marc Andreessen has a startup called Ning, which helps people—what else—create their own social-networking sites.

So what advice do I have for dealing with the friend spam and keeping on top of all these new services? Every once in a while, turn off your computer and go hang out with your friends. TR

Entrepreneur Jonathan Abrams is founder and CEO of the events-sharing service Socializr.

CLIMATE CHANGE

Sea-Level Riddle

Determining how fast ice sheets are melting is critical to future policy decisions, says **Richard Alley.**

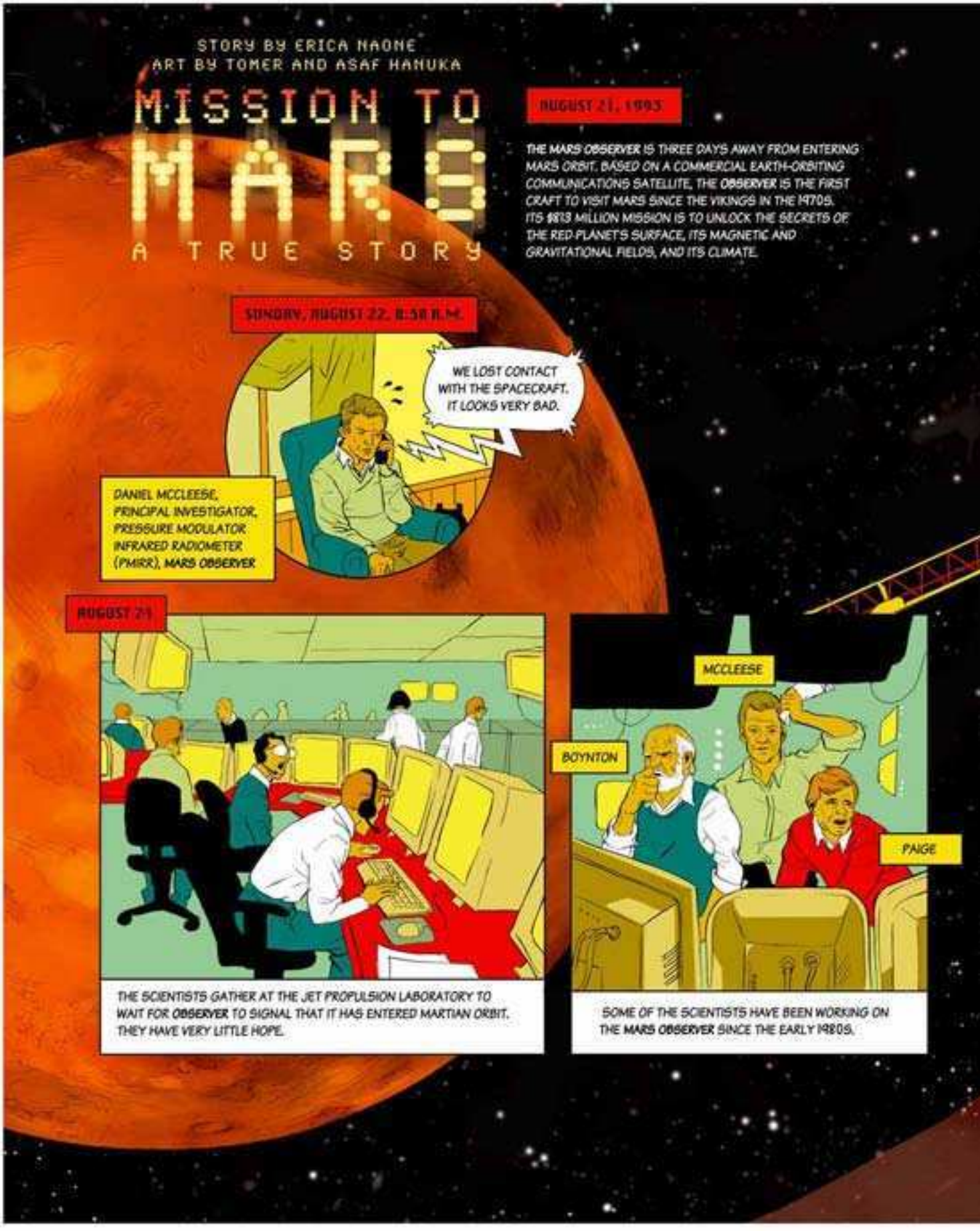
Are the Greenland and Antarctic ice sheets our friends, which will moderate sea-level rise over the next century as polar snowfall increases? Or are they ticking bombs, soon to unleash floods on the world's coasts? The uncomfortable fact is that while the ice is looking less and less friendly *(see "Measuring the Polar Meltdown," p. 54)*, we're really not sure. The United States has joined almost 200 other countries in seeking "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" under Article Two of the U.N. Framework Convention on Climate Change. Exactly what constitutes "dangerous interference" can be debated, but substantial ice-sheet shrinkage causing meters of sea-level rise is a strong candidate.

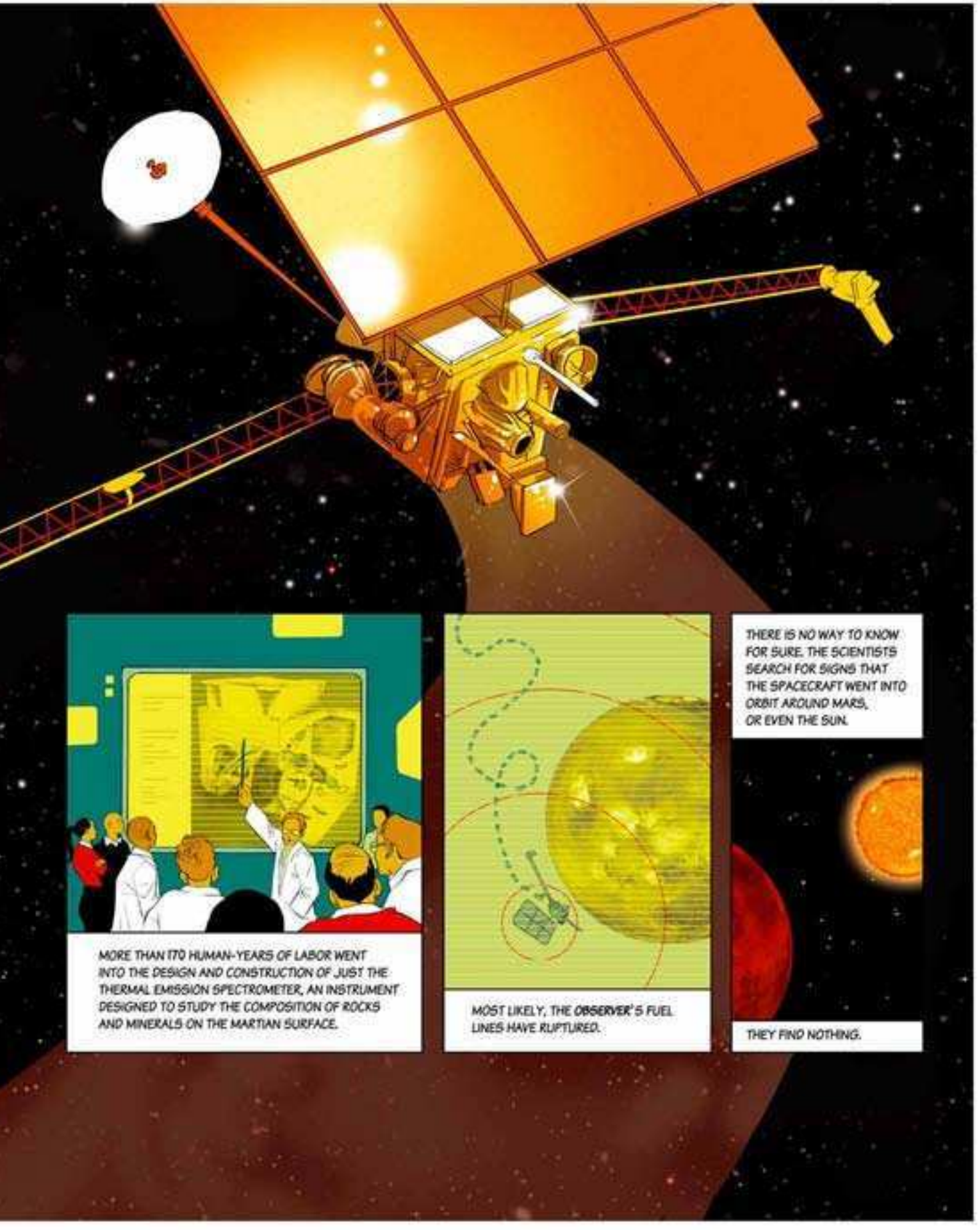
In 2001, the U.N. Intergovernmental Panel on Climate Change (IPCC) described the great difficulties in predicting ice-sheet changes but projected slight net growth over the next century. By 2007, ice-flow instabilities had occurred in Greenland and Antarctica, apparently from warming, and the ice sheets were contributing slightly to sea-level rise. The IPCC noted that whole-ice-sheet models had not anticipated and could not reproduce the changes, and so could not adequately project future changes. Although our understanding of most factors affecting sea-level rise had improved, 2007 projections by the IPCC excluded "future rapid dynamical changes in ice flow" because "understanding … is too limited to provide a best estimate or an upper bound for sea level rise."

Work is under way to improve and test the existing ice-sheet models. I know of no plausible scenarios under which an ice sheet would be lost over the next few decades, but the ongoing work does suggest that in the next decades, warming may initiate substantial change, perhaps crossing a threshold leading to much greater shrinkage or loss over centuries.

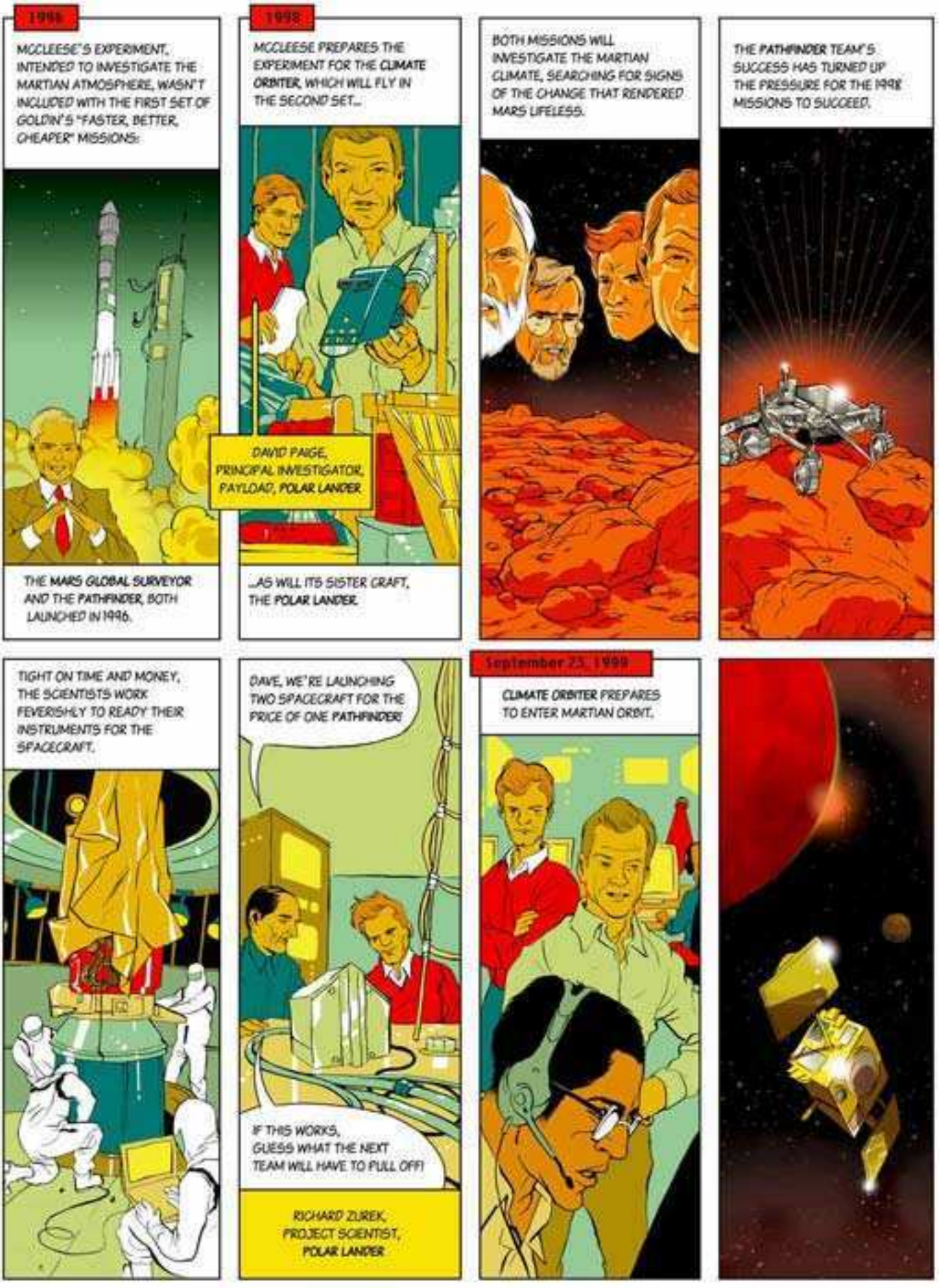
Ice sheets spread like pancake batter, on a greased griddle in some places but on a bumpy waffle iron in others, with islands blocking floating ice shelves that restrain the ice behind them. Warming's most immediate impact may be to cause melting beneath those ice shelves, but in some places we don't know the water depth well enough to build models. Despite heroic efforts, the waffle-iron and greased-griddle characteristics of the substrate are only partially mapped. The ability of surface meltwater to penetrate the ice and enhance lubrication is poorly understood. Recent changes were observed by satellites and other platforms, some of which may be lost to inadequate funding. And in global-climate models, the ice sheets remain inert white lumps, uncoupled from their surroundings. Small, mostly academic groups are working on ice-flow models, but the big, primarily government-run centers that guide policy makers do not have the funding for ice-sheet modeling that they do for atmospheric, ocean, and land-surface modeling. Having played a small role in the 2007 IPCC, I believe that the assessment of the ice sheets was done well and that lack of a "best estimate or upper bound for sea level rise" reflects the science. But policy makers seeking economically and ecologically wise ways to avoid dangerous anthropogenic climate interference surely deserve additional guidance. That will not come soon without additional focus on the ice sheets. TR

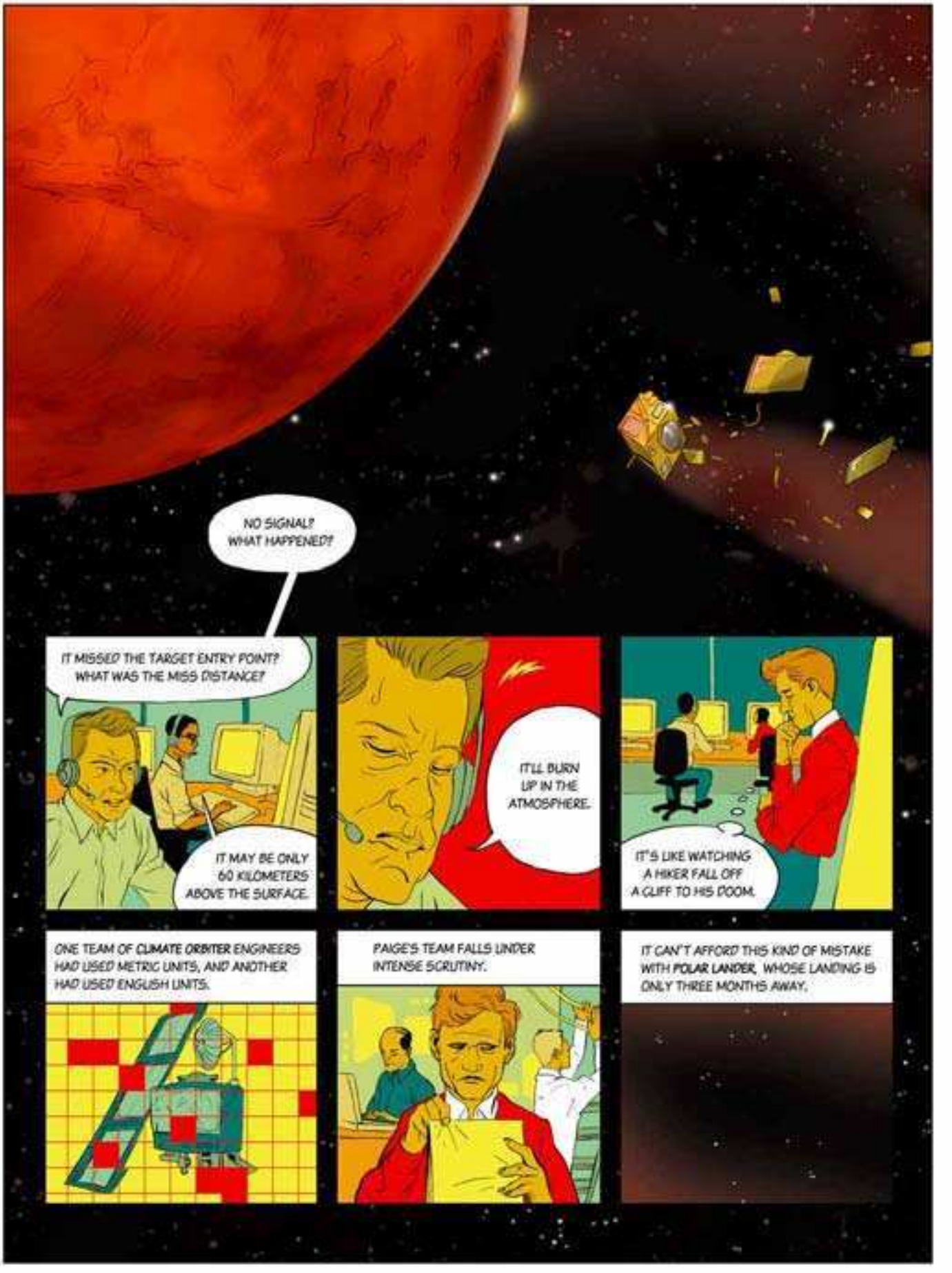
Richard Alley, a professor of geosciences at Pennsylvania State University, was lead author of the chapter on Earth's cryosphere in the most recent IPCC report.

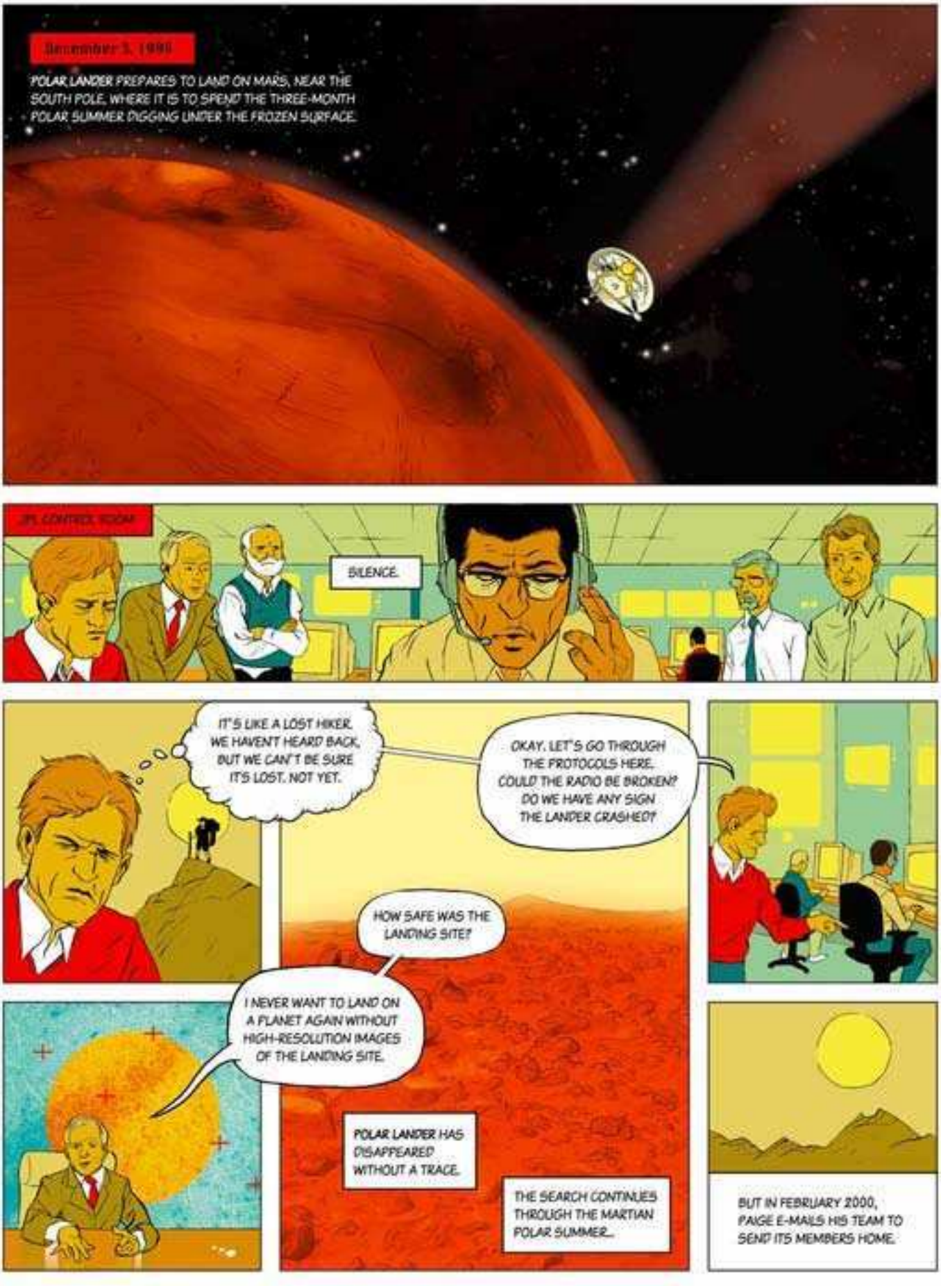

STORY BY ERICA NAONE
ART BY TOMER AND ASAF HANUKA
MISSION TO MARS
A TRUE STORY
AUGUST 21, 1993
THE MARS OBSERVER IS THREE DAYS AWAY FROM ENTERING MARS ORBIT. BASED ON A COMMERCIAL EARTH-ORBITING COMMUNICATIONS SATELLITE, THE OBSERVER IS THE FIRST CRAFT TO VISIT MARS SINCE THE VIKINGS IN THE 1970S. ITS $813 MILLION MISSION IS TO UNLOCK THE SECRETS OF THE RED PLANET'S SURFACE, ITS MAGNETIC AND GRAVITATIONAL FIELDS, AND ITS CLIMATE.
SUNDAY, AUGUST 22, 8:58 A.M.
WE LOST CONTACT WITH THE SPACECRAFT. IT LOOKS VERY BAD.
DANIEL MCCLEESE, PRINCIPAL INVESTIGATOR, PRESSURE MODULATOR INFRARED RADIOMETER (PMIRR), MARS OBSERVER
AUGUST 21
THE SCIENTISTS GATHER AT THE JET PROPULSION LABORATORY TO WAIT FOR OBSERVER TO SIGNAL THAT IT HAS ENTERED MARTIAN ORBIT. THEY HAVE VERY LITTLE HOPE.
MCCLEESE
BOYNTON
PAIGE
SOME OF THE SCIENTISTS HAVE BEEN WORKING ON THE MARS OBSERVER SINCE THE EARLY 1980S.

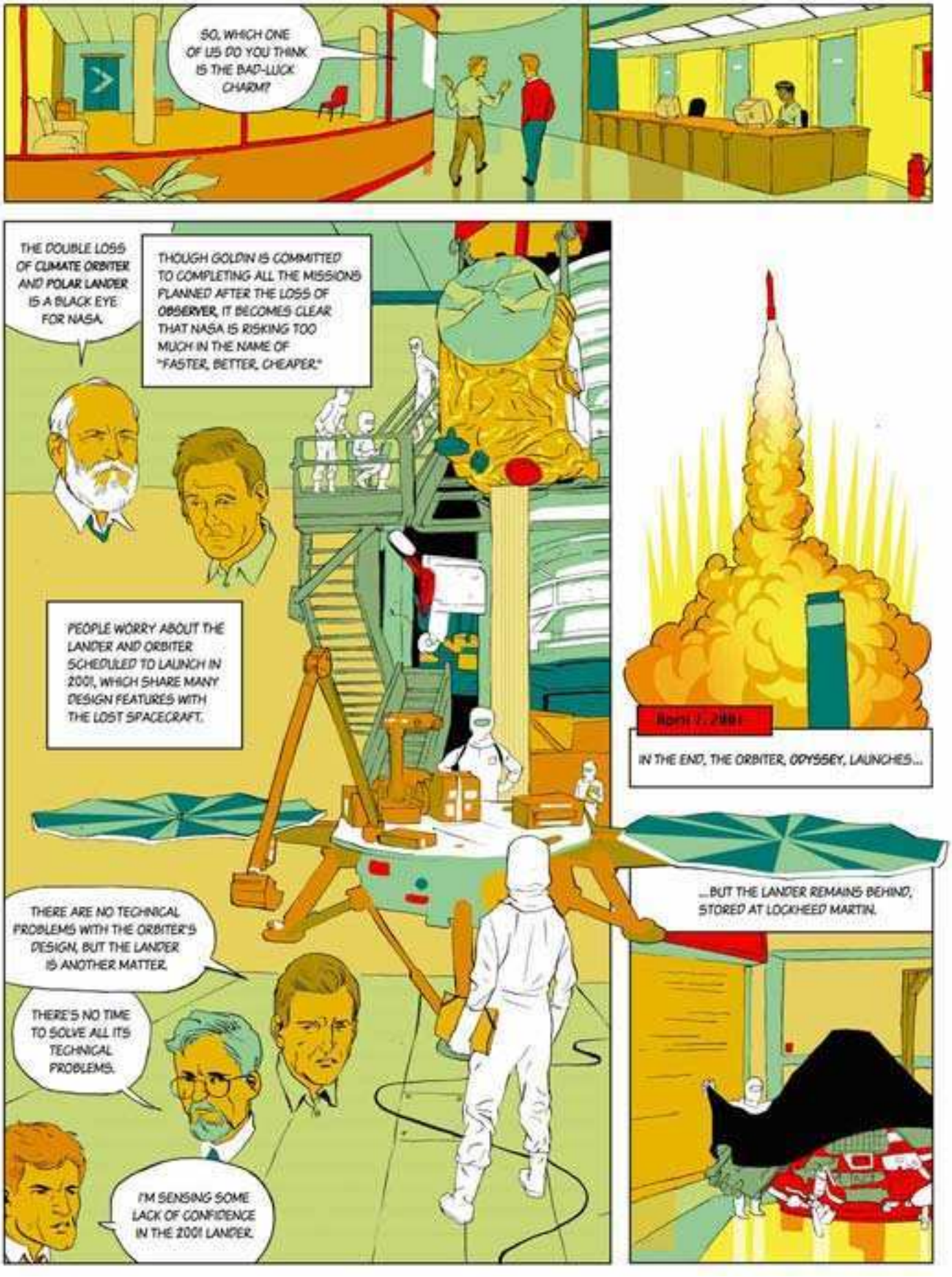

MORE THAN 170 HUMAN-YEARS OF LABOR WENT INTO THE DESIGN AND CONSTRUCTION OF JUST THE THERMAL EMISSION SPECTROMETER, AN INSTRUMENT DESIGNED TO STUDY THE COMPOSITION OF ROCKS AND MINERALS ON THE MARTIAN SURFACE.
MOST LIKELY, THE OBSERVER'S FUEL LINES HAVE RUPTURED.
THERE IS NO WAY TO KNOW FOR SURE. THE SCIENTISTS SEARCH FOR SIGNS THAT THE SPACECRAFT WENT INTO ORBIT AROUND MARS, OR EVEN THE SUN.
THEY FIND NOTHING.


1993
NASA HAS LAUNCHED NO REPLACEMENT FOR OBSERVER, THOUGH THE CUSTOM HAS BEEN TO SEND SPACECRAFT OUT IN PAIRS, IN CASE ONE IS LOST...
...COPIES OF THE INSTRUMENTS ON OBSERVER REMAIN ON THE GROUND, IN STORAGE AT THE SPACE CONTRACTOR'S FACILITY, UNASSEMBLED.
WILLIAM BOYNTON, PRINCIPAL INVESTIGATOR, GAMMA RAY SPECTROMETER, MARS OBSERVER
WE HAVE SOME SPARE PARTS. WE COULD BUILD ANOTHER OBSERVER AND LAUNCH AGAIN.
DANIEL GOLDIN, HEAD OF NASA
IT'S TOO MUCH TO RISK ALL THE INSTRUMENTS IN ONE CRAFT. WE CAN FLY THEM IN THREE MISSIONS, CHEAPER MISSIONS.
GO TO MARS EVERY TWO YEARS, NOT EVERY TEN. WE'LL WIN SOME AND LOSE SOME...
BUT WE WON'T LOSE ALL.
MEANWHILE, AT DAN MCCLEESE'S DESK...
IT'S STRANGE. AFTER ALL THESE YEARS TO COMPETE WITH THE PEOPLE I'VE BEEN WORKING WITH. BUT I NEED TO GET MY EXPERIMENT ON THE FIRST MISSION.
HOW CAN I BE SURE NASA WILL REALLY FLY THE SECOND? OR THE THIRD?


1996
MCCLEESE'S EXPERIMENT, INTENDED TO INVESTIGATE THE MARTIAN ATMOSPHERE, WASN'T INCLUDED WITH THE FIRST SET OF GOLDIN'S "FASTER, BETTER, CHEAPER" MISSIONS:
THE MARS GLOBAL SURVEYOR AND THE PATHFINDER, BOTH LAUNCHED IN 1996.
1998
MCCLEESE PREPARES THE EXPERIMENT FOR THE CLIMATE ORBITER, WHICH WILL FLY IN THE SECOND SET...
DAVID PAIGE, PRINCIPAL INVESTIGATOR, PAYLOAD, POLAR LANDER
...AS WILL ITS SISTER CRAFT, THE POLAR LANDER.
BOTH MISSIONS WILL INVESTIGATE THE MARTIAN CLIMATE, SEARCHING FOR SIGNS OF THE CHANGE THAT RENDERED MARS LIFELESS.
THE PATHFINDER TEAM'S SUCCESS HAS TURNED UP THE PRESSURE FOR THE 1998 MISSIONS TO SUCCEED.
TIGHT ON TIME AND MONEY, THE SCIENTISTS WORK FEVERISHLY TO READY THEIR INSTRUMENTS FOR THE SPACECRAFT.
DAVE, WE'RE LAUNCHING TWO SPACECRAFT FOR THE PRICE OF ONE PATHFINDER!
IF THIS WORKS, GUESS WHAT THE NEXT TEAM WILL HAVE TO PULL OFF!
RICHARD ZUREK, PROJECT SCIENTIST, POLAR LANDER
September 23, 1999
CLIMATE ORBITER PREPARES TO ENTER MARTIAN ORBIT.


NO SIGNAL? WHAT HAPPENED?
IT MISSED THE TARGET ENTRY POINT? WHAT WAS THE MISS DISTANCE?
IT MAY BE ONLY 60 KILOMETERS ABOVE THE SURFACE.
IT'LL BURN UP IN THE ATMOSPHERE.
IT'S LIKE WATCHING A HIKER FALL OFF A CLIFF TO HIS DOOM.
ONE TEAM OF CLIMATE ORBITER ENGINEERS HAD USED METRIC UNITS, AND ANOTHER HAD USED ENGLISH UNITS.
PAIGE'S TEAM FALLS UNDER INTENSE SCRUTINY.
IT CAN'T AFFORD THIS KIND OF MISTAKE WITH POLAR LANDER, WHOSE LANDING IS ONLY THREE MONTHS AWAY.

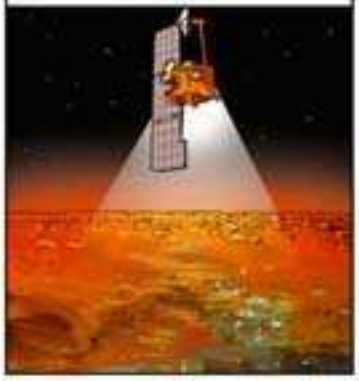

December 3, 1999
POLAR LANDER PREPARES TO LAND ON MARS, NEAR THE SOUTH POLE, WHERE IT IS TO SPEND THE THREE-MONTH POLAR SUMMER DIGGING UNDER THE FROZEN SURFACE.
JPL CONTROL ROOM
SILENCE.
IT'S LIKE A LOST HIKER. WE HAVEN'T HEARD BACK, BUT WE CAN'T BE SURE IT'S LOST. NOT YET.
OKAY. LET'S GO THROUGH THE PROTOCOLS HERE. COULD THE RADIO BE BROKEN? DO WE HAVE ANY SIGN THE LANDER CRASHED?
HOW SAFE WAS THE LANDING SITE?
I NEVER WANT TO LAND ON A PLANET AGAIN WITHOUT HIGH-RESOLUTION IMAGES OF THE LANDING SITE.
POLAR LANDER HAS DISAPPEARED WITHOUT A TRACE.
THE SEARCH CONTINUES THROUGH THE MARTIAN POLAR SUMMER...
BUT IN FEBRUARY 2000, PAIGE E-MAILS HIS TEAM TO SEND ITS MEMBERS HOME.


SO, WHICH ONE OF US DO YOU THINK IS THE BAD-LUCK CHARM?
THE DOUBLE LOSS OF CLIMATE ORBITER AND POLAR LANDER IS A BLACK EYE FOR NASA.
THOUGH GOLDIN IS COMMITTED TO COMPLETING ALL THE MISSIONS PLANNED AFTER THE LOSS OF OBSERVER, IT BECOMES CLEAR THAT NASA IS RISKING TOO MUCH IN THE NAME OF "FASTER, BETTER, CHEAPER."
PEOPLE WORRY ABOUT THE LANDER AND ORBITER SCHEDULED TO LAUNCH IN 2001, WHICH SHARE MANY DESIGN FEATURES WITH THE LOST SPACECRAFT.
THERE ARE NO TECHNICAL PROBLEMS WITH THE ORBITER'S DESIGN, BUT THE LANDER IS ANOTHER MATTER.
THERE'S NO TIME TO SOLVE ALL ITS TECHNICAL PROBLEMS.
I'M SENSING SOME LACK OF CONFIDENCE IN THE 2001 LANDER.
IN THE END, THE ORBITER, ODYSSEY, LAUNCHES...
...BUT THE LANDER REMAINS BEHIND, STORED AT LOCKHEED MARTIN.

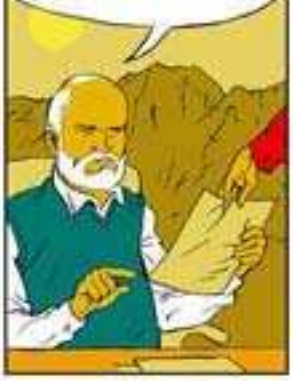
2002

BOYNTON IS PRINCIPAL INVESTIGATOR FOR *ODYSSEY'S GAMMA RAY SPECTROMETER EXPERIMENT*, WHICH HE FIRST TRIED TO RUN ON THE *OBSERVER*.

THE INSTRUMENT SEARCHES FOR EVIDENCE OF WATER AND ICE IN MARTIAN SOIL.



SO MUCH HYDROGEN. THIS COULD MEAN HUGE QUANTITIES OF ICE.



AFTER ALL THESE DISAPPOINTMENTS, IT'S HARD TO DESCRIBE WHAT IT'S LIKE TO GET DATA. THE JOY MORE THAN MAKES UP FOR THE LOSSES.

March 10, 2006

PAIGE, MCCLEESE, AND ZUREK HAVE GONE ON TO WORK ON THE *MARS RECONNAISSANCE ORBITER*, WHICH WILL STUDY THE HISTORY OF WATER ON MARS AND SCOUT FUTURE LANDING SITES.

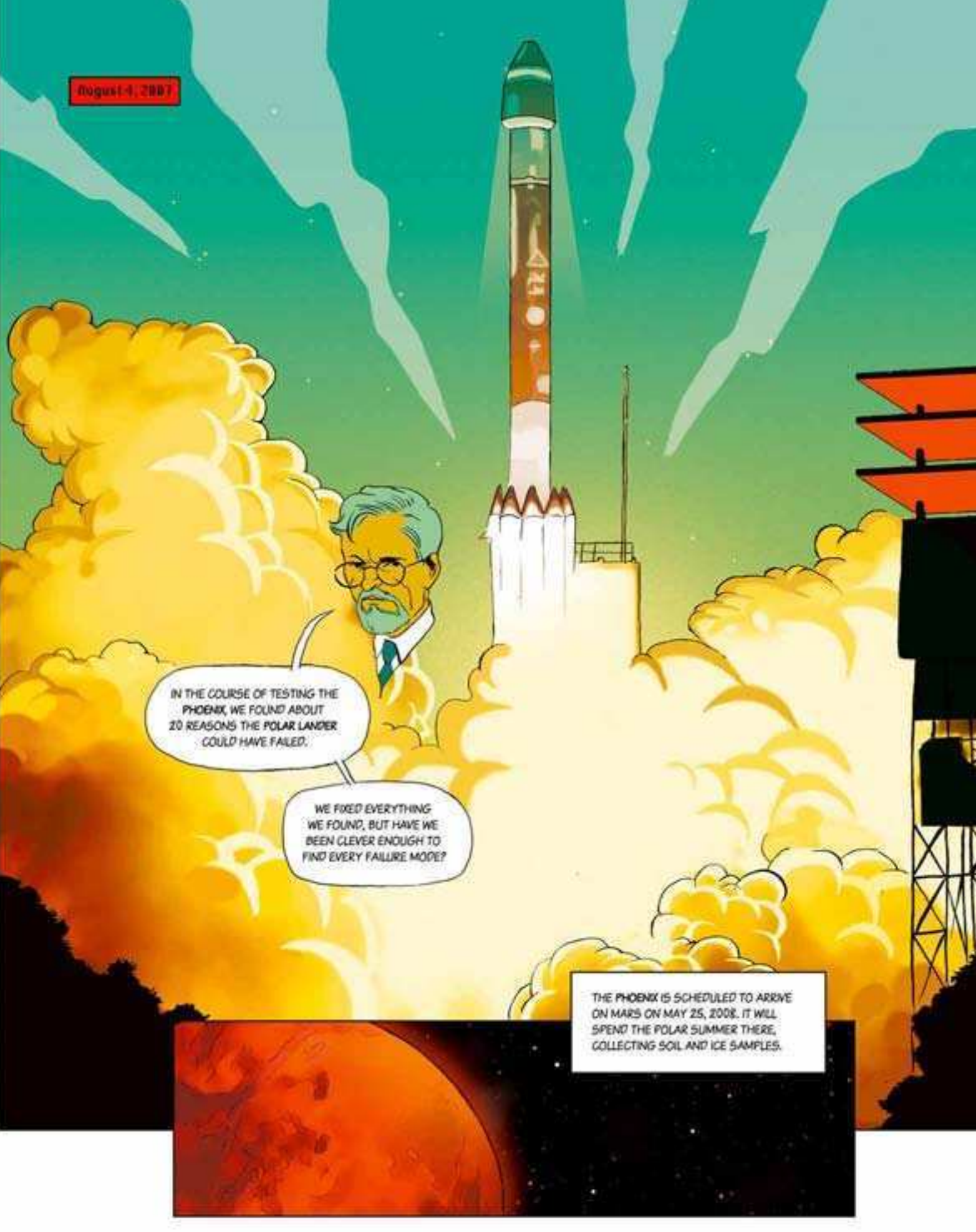
THE SPACECRAFT CARRIES THE CLIMATE SOUNDER, HEIR TO THE PMIRR INSTRUMENTS LOST WITH *CLIMATE ORBITER* AND *OBSERVER*.

IT SUCCESSFULLY REACHES ORBIT...

...AND THE SCIENTISTS GET DATA TO WORK WITH.

BUT NOT EVERYONE HAS LET GO OF THE LANDER.


ODYSSEY AND MARS RECONNAISSANCE ORBITER ARE SUCCESSES.
AND THE ROVER MISSIONS SPIRIT AND OPPORTUNITY, LAUNCHED IN 2003, HAVE REVEALED A GREAT DEAL ABOUT THE SURFACE OF THE RED PLANET.
2005
PETER SMITH, PRINCIPAL INVESTIGATOR, PHOENIX POLAR MISSION
TO SEE THE NORTH POLE—SUCH AN INCREDIBLE, ALIEN-LOOKING LANDSCAPE.
BUT ANOTHER OPPORTUNITY IS COMING UP TO LAND IN A POLAR REGION, AND PETER SMITH PROPOSES THE PHOENIX MISSION, WHICH WOULD RESUSCITATE THE 2001 LANDER AND RETRY SOME EXPERIMENTS PLANNED FOR THE LOST POLAR LANDER.
IT COSTS $10,000 JUST TO OPEN THE BOX.
BUT I HAVE TO SEE IF THE 2001 LANDER IS SOMETHING WE CAN REVIVE.
FIFTEEN YEARS OF DEVELOPMENT—WE CAN'T WASTE THAT.
SUCH A BEAUTIFUL SPACECRAFT.
AMAZING THAT ENGINEERS CAN BUILD SOMETHING LIKE THIS.
IT'S LIKE BUILDING THE HUMAN BODY'S VASCULAR OR NERVOUS SYSTEM.
OUR JOB NOW IS TO FIND ITS FLAWS, AND FIX THEM.
THE PHOENIX, RISING FROM THE ASHES OF THE 2001 LANDER AND THE POLAR LANDER BEFORE IT.


August 4, 2007
IN THE COURSE OF TESTING THE PHOENIX, WE FOUND ABOUT 20 REASONS THE POLAR LANDER COULD HAVE FAILED.
WE FIXED EVERYTHING WE FOUND, BUT HAVE WE BEEN CLEVER ENOUGH TO FIND EVERY FAILURE MODE?
THE PHOENIX IS SCHEDULED TO ARRIVE ON MARS ON MAY 25, 2008. IT WILL SPEND THE POLAR SUMMER THERE, COLLECTING SOIL AND ICE SAMPLES.

The Blow-Up

The quants behind Wall Street's summer of scary numbers.

By Bryant Urstadt
Illustrations by Julien Pacaud

On Wednesday, August 8, not long after the markets closed, 200 of the smartest people on Wall Street gathered in a conference room at Four World Financial Center, the 34-story headquarters of Merrill Lynch. August is usually a slow month, but the rows of chairs were full, and highly paid financial engineers were standing by the windows at the back, which looked out over black Town Cars below and the Hudson River beyond. They didn't look like Masters of the Universe; they looked like members of a chess club. They were "quants," and they had a lot to talk about, for their work was at the heart of one of the most worrisome summer markets in decades.

The conference was sponsored by the International Association of Financial Engineers (IAFE), and its title asked, "Is Subprime the Canary in the Mine?" "Subprime" borrowers are home buyers whose poor credit history means they don't qualify for market interest rates. Loans to subprime borrowers, which have become more common in recent years, typically have variable interest rates; as those rates rose, many borrowers were failing to meet their mortgage payments. Their defaults, in turn, had triggered unexpected problems in the market for financial instruments known as derivatives.

A derivative is a tradable product whose value is based on, or "derived" from, an underlying security. The classic example of a derivative is the option to buy a stock at some time in the future. In comparison, more recent derivatives are extraordinarily complex, and they had been invented by quants like the ones at the Merrill Lynch headquarters.

Things had started to go wrong in June, when the weakness in the subprime market had led to the collapse of two huge funds at the investment bank Bear Stearns, costing investors some $1.6 billion. When the quants gathered in August, the most pessimistic among them imagined that the collapse of the subprime market could lead to a shortage of credit as banks dealt with defaults. That would chill the economy, causing worldwide job losses, still more defaults, decreased spending, and withdrawals from the stock market, culminating in a global recession, or worse.

The panel was moderated by Leslie Rahl, an MIT graduate and the founder of Capital Market Risk Advisors. Her job is to advise companies on risk and help them understand the products quants invent. But understanding was in short supply in August. Some of the quants' financial products had collapsed in price, with unexpected consequences in another financial sector: the trading of equities.

The stock market had plunged in July and had been behaving erratically since. In the weeks after the conference, an organizing narrative of sorts would develop. But at the time, the economic view was dizzying. The market would drop precipitously over the course of a day, then rebound nearly to its previous level in the last 45 minutes of trading. Stranger still, stocks with strong financial reports and a good outlook were falling; these were the blue chips, which normally rose in uncertain times. Stocks with weak financials and a gray future were rising. These were normally the dogs that got dumped.

No one quite knew why, yet, but the market's odd behavior would turn out to be closely linked to the work of the quants. In addition to creating arcane financial products, quants have been pushing the frontiers of computer-driven trading systems, and not enough of those systems were working the way they were supposed to—or, to put it more precisely, the way they were supposed to work turned out to be counterproductive in volatile times like these.

Quants like the ones at the August conference were knee deep in the troubles threatening the global financial system. It all raised two very good questions: Who exactly *are* the quants? And what do they really *do*?

"Quant" is an elastic word that has meant different things at different times. Historically, the term referred to backroom technicians who used quantitative analysis to support the bankers who sold financial instruments. It came into wider use in the 1980s, when academics—pure mathematicians and physicists, mostly—began to appear in the financial world in larger numbers. Classic geeks, the new-


$S\Phi(d_1) - Ke^{rT}$
$dS_t = \mu S$
$C(S,T) =$

comers were at first treated as déclassé immigrants by the financial establishment. Emanuel Derman was a theoretical physicist at Columbia University before he joined Goldman Sachs in 1985, and he remembers in his fine memoir *My Life as a Quant* when "it was bad taste for two consenting adults to talk math or Unix or C in the company of traders, salespeople, and bankers." But success lent the quants credibility. What was at first a disdainful term was cheerfully embraced by those whom it was originally meant to insult. It finally came to encompass a larger group of people, including, most broadly, anyone involved in mathematical or computational finance. In this article, the word "quant" refers to any practitioner of quantitative finance, a wide-ranging discipline that includes, among other things, the pricing of financial instruments, the evaluation of risk, and the search for exploitable patterns in market data.

A quant sees the financial world through a mathematical lens. This does not necessarily describe the average Wall Street salesperson or trader, whose success is often based as much on intuition and, maybe more important, connections and personal charisma as on any understanding of a topic like stochastic calculus. To give some idea of how far the quant mind is from that of the typical financier, stochastic calculus—a branch of mathematics dealing with randomness—is sometimes derided by quants as "folk math." The quant, unlike his slicker counterpart, seeks to understand and profit from the markets on a purely numerical basis. Or as Herbert Blank, a quant who devises algorithms for evaluating the financial health of companies, says, "If you think you can find out what you need to know by going to see the management of a company, then I have nothing to say to you."

To give some idea of how far the quant mind is from that of the typical financier, stochastic calculus—a branch of mathematics dealing with randomness—is sometimes derided by quants as "folk math."

If quants in one guise or another have been around for a while, they have also made trouble before. The hedge fund Long-Term Capital Management, which collapsed in August 1998, boasted some of the founders of the field among its directors and officers. Nonetheless, in recent years, quants' numbers and influence have grown. Over-the-counter derivatives, such as the ones at the heart of the subprime crisis, have become more popular, fueling a boom in lending by making loans easier to trade. The value of over-the-counter derivatives, one shorthand measure of activity in the market, went from $298 trillion in December 2005 to $415 trillion a year later, according to statistics kept by the Bank for International Settlements. By some measures, the money invested in two of the most common types of quant funds has grown 60 percent in the last two years (including both expanding assets and new investments), and the funds have generated some of the highest returns in the financial industry.

They're also among the industry's most mysterious organizations. Firms that keep their methods secret are known as "black boxes," and the quant-driven hedge funds are as black as any. It is not unusual for billions of dollars to be invested in such firms with little revealed except the results. Previous results, though, can be a powerful incentive for giving money to someone who won't tell you what he's going to do with it. A case in point is James Simons's Renaissance Technologies, which has earned an average of more than 30 percent a year since its founding in 1988. Like other quant funds, it is ferociously secretive. Still, so many investors have trusted Simons that the two funds under his management now total more than $30 billion. In 2006 alone, he earned $1.7 billion running the fund.

The press often refers to Simons as the world's leading quant. A world-class mathematician with a PhD from the University of California, Berkeley, he spent years in academia, making significant contributions to mathematics. He worked primarily in geometry and in a subfield called differential geometry, where his most prominent contribution was the Chern-Simons theory, a topological description of quantum field behavior that has been useful to string theorists. Many of his employees have backgrounds in physics, astronomy, and mathematics.

The quants of Renaissance Technologies are unusual in that many might have enjoyed significant careers in academia. But quants of a less exalted sort are becoming ubiquitous at financial institutions. There are quants at investment banks, developing new loan structures. There are quants at hedge funds, crunching years of market data to develop trading algorithms that computers execute in milliseconds. And there are more and more quants at pension funds, trying to understand and value the tools created by the banking quants, and trying to evaluate the methods of the investing quants.

"We used to send our graduates mainly to the big banks," says Andrew Lo, the director of MIT's Laboratory for Financial Engineering, where many quants are trained. "Now they're going everywhere, to pension funds, insurance companies, and companies that aren't finance companies at all." MIT's lab was founded in 1992, one of a host of academic programs in the discipline that have sprung up

on campuses around the United States and abroad; a new institute at the University of Oxford is one of the most recent additions. "Financial markets and investment processes are becoming more quant across the board," says Lo.

To understand who they were and what they were doing, I spoke with current and former quants, on and off the record. Many would speak happily and at length. Others spoke guardedly or anonymously—especially those using proprietary analysis and algorithms to conduct trades. I read memoirs of quants—a recently expanding genre—and dipped into an introductory textbook for quants, *Paul Wilmott Introduces Quantitative Finance*, a 722-page condensation of the author's 1,500-page, three-volume anvil of a book, *Paul Wilmott on Quantitative Finance*. And I went to a quant drinking party, which convened in the basement of a pub next to Grand Central Station. The name of that event proves, as much as anything, that the quants have geek in their veins: it was the August meeting of the New York chapter of the Quantitative Work Alliance for Applied Finance, Education, and Wisdom, or QWAFAFEW.

Though derivatives were simpler once, they were never very simple. The breakthrough in the valuation of derivatives in general, and options in particular, was the model and formula know as Black-Scholes, first proposed by Fischer Black and Myron Scholes in the 1970s and formalized by Robert Merton in 1973. (Merton, like so many of the best quants, came not out of Wall Street but out of academia, earning a PhD in economics from MIT in 1970.)

In quantitative finance, the formal expression of Black-Scholes by Robert Merton is so important that everything that followed has been called a "footnote." The Black-Scholes model assumes that a stock's price changes partly for predictable reasons and partly because of random events; the random element is called the stock's "volatility." The idea can be represented mathematically by a simple equation:

$$dS_t = \mu S_t\,dt + \sigma S_t\,dW_t$$

S_t is the value of the stock, and dS_t is the change in stock price. The symbol $\mu S_t dt$ represents the stock's predictable change and $\sigma S_t dW_t$ its volatility. That final, kabbalistic combination of letters, dW_t, is the mathematical expression for randomness, known as either Brownian motion or the Wiener process. (Chemically, Brownian motion is the random movement of particles in solution, identified by the botanist Robert Brown in 1828 and mathematically described by the great MIT mathematician Norbert Wiener. Black-Scholes shares some qualities with heat and diffusion equations, which describe everyday events like the flow of heat and the dispersion of populations. That some physical processes seem relevant to finance has inspired all kinds of far-out work, such as efforts to bend general relativity to a theory of finance.) Black-Scholes prices an option according to the amount of randomness in a stock's price; the greater the randomness, the higher the stock could climb, and thus the more expensive the option.

Quants have since refined Black-Scholes, and with the increasing power of computers, they have developed other, more processing-intensive methods of valuing derivatives. In Monte Carlo simulations, for instance, powerful computers model the performance of a stock millions of times and then average the results. Where Black-Scholes, as a mathematical shortcut, assigns a constant value to a stock's volatility, Monte Carlo simulations vary the volatility itself. In theory, this provides a better approximation of price fluctuations in the real world. And quants have devised yet more arcane methods of derivatives pricing. Some particularly complicated models track other economic factors—like the stock market as a whole, or even larger macroeconomic factors—in addition to a stock's price.

Running such computationally intensive simulations has become a lot easier in the last decade. Gregg Berman, a former experimental astrophysicist who left the academy for the world of finance in 1993, is one of what he calls "a plethora of PhDs" at RiskMetrics, a firm that provides models, tools, and data to the majority of important banks, brokerages, and hedge funds. (Among other things, the company tries to predict how a derivative will behave in a variety of market conditions—how it might respond, for instance, to weakening exchange rates or increased interest rates.) When Berman started in the business, he says, "full-blown simulations [of the Monte Carlo type] were rare." Now that computers can be so easily linked, however, Berman might put as many as 1,000 processors to work at once to run "simulations within simulations," which might measure risk on a product like a mortgage-backed security.

The net result of this improved ability to assign values to increasingly complex derivatives was an explosion in their variety. That meant there was a derivative to suit every investor's appetite for risk. In consequence, investors were increasingly willing to put more money into derivatives.

Recently, one of the most popular of these new instruments has been collateralized debt obligations, or CDOs. Crucially for our story, CDOs are also the product most closely associated with the summer's subprime mess. The CDO has been called a "derivative of a derivative," and to further confuse things, there are CDOs of CDOs, and even CDOs of CDOs of CDOs. A CDO combines both high- and low-risk securities that might derive their cash flow from mortgages, car loans, or more esoteric sources like movie revenues or airplane leases. Investors in a CDO can buy the rights to different levels of income and associated risk, called "tranches." Generally, the most risky tranche of a

CDO pays the most income. Created by quants and priced by quants, CDOs have become a popular way for hedge funds, pension funds, insurance companies, and other investors to buy pieces of high-risk but high-profit sectors like subprime loans. According to the Securities Industry and Financial Markets Association, annual issues of CDOs worldwide nearly doubled between 2005 and 2006, going from $249.3 billion to $488.6 billion.

The quants who devise such derivatives work more or less in public view. They're obscured mainly by the complexity of their work. But our knowledge of the quants who design trading strategies is additionally occluded by the secrecy of the big fund operators like Renaissance Technologies. I did manage to speak with some current traders, who gave me a general idea of their approach, and with some ex-traders, who were slightly more specific.

One common method that quants use to identify market opportunities is pairs trading. Pairs trading involves trying to find securities that rise in tandem, or that tend to go in opposite directions. If that relationship falters—if, say, the values of two stocks that travel together suddenly diverge—it's likely to indicate that one stock is undervalued or overvalued. Which stock is which is irrelevant: a trader who simultaneously bets that one will go up and the other one down will probably make money. It's a strategy that lends itself to the use of computers, which can sort through huge numbers of price correlations over many years of stored data—although the final decision to speculate on the relative pricing of paired stocks generally rests with a fund's managers.

Quants have also been pursuing a strategy known as "capital structure arbitrage," which seeks to exploit inefficient pricing of a company's bonds versus its stocks. Again, computers do the searching, looking for instances where, for one reason or another, the securities are slightly misaligned.

In a similar technique, Max Kogler, a principal at the newly launched MM Capital in New York, uses computers to look for inconsistencies in value between the option on an index fund and the options on the stocks that compose that index. Kogler has a master's from the University of Cambridge in pure mathematics with a focus on statistics. He says his algorithms look for "baskets of options that are not doing what they're supposed to be doing." When his computers find such a basket, he and his partners discuss whether or not to buy.

Kogler runs his algorithms on "one Linux box." "Part of the allure of our algorithm," he said in an e-mail, "is that it cuts down computational requirements dramatically. Nonetheless, you'll want to have a speedy machine with pretty decent clock speed and a couple of parallel CPUs."

In what's called nondiscretionary trading, computers both find the inefficiencies and execute the trades. The Aite Group, a financial-services research firm, estimates that roughly 38 percent of all equities may be traded automatically, a number it expects to increase to 53 percent in three years.

Computers also underlie another developing frontier, high-frequency trading, which is a fantastically exaggerated form of day trading. The computer looks for patterns and inefficiencies over minutes or seconds rather than hours or days. An algorithm, for instance, might look for patterns in trading while the Japanese are at lunch, or in the moments before an important announcement. There is a massive amount of such data to crunch. Olsen Financial Technologies, a Zürich-based firm that offers data for sale, says it collects as many as a million price updates per day.

One trader I spoke with at a $10 billion hedge fund based in New York said that his computer executed 1,000 to 1,500 trades daily (although he noted that they were not what he called "intra-day" trades). His inch-thick employment contract precluded my using his name, but he did talk a little bit about his approach. "Our system has a touch of genetic theory and a touch of physics," he said. By genetic theory, he meant that his computer generates algorithms randomly, in the same way that genes randomly mutate. He then tests the algorithms against historical data to see if they work. He loves the challenge of cracking the behavior of something as complex as a market; as he put it, "It's like I'm trying to compute the universe." Like most quants, the trader professed disdain for the "sixth sense" of the traditional trader, as well as for old-fashioned analysts who spent time interviewing executives and evaluating a company's "story."

High-frequency trading is likely to become more common as the New York Stock Exchange gets closer and closer to a fully automated system. Already, 1,500 trades a day is conservative; the computers of some high-frequency traders execute hundreds of thousands of trades every day.

Linked with high-frequency trading is the developing science of event processing, in which the computer reads, interprets, and acts upon the news. A trade in response to an FDA announcement, for example, could be made in milliseconds. Capitalizing on this trend, Reuters recently introduced a service called Reuters NewsScope Archive, which tags Reuters-issued articles with digital IDs so that an article can be downloaded, analyzed for useful information, and acted upon almost instantly.

All this works great, until it doesn't. "Everything falls apart when you're dealing with an outlier event," says the trader at the $10 billion fund, using a statistician's term for those events that exist at the farthest reaches of probability. "It's easy to misjudge your results when you're successful. Those one-in-a-hundred events can easily happen twice a year."

The events of August were outliers, and they were of the quants' own making. (Some dispute that verdict: see "On Quants," p. 24.) To begin with, quants were indirectly responsible for the boom in housing loans offered to shaky candidates.

Derivatives allow banks to trade their mortgages like bubble-gum cards, and the separation of the holder of a loan from the writer of a loan tended to create an overgenerous breed of loan officer. The banks, in turn, were attracted by the enormous market for derivatives like CDOs. That market was fueled by hedge funds' appetite for products that were a little riskier and would thus produce a higher return. And the quants who specialized in risk assessment abetted the decision to buy CDOs, because they assumed that the credit market would enjoy nine or so years of relatively benign volatility.

It was a perfectly rational assumption; it just happened to be wrong. Matthew Rothman, a senior analyst in quantitative strategies at Lehman Brothers, called the summer a time of "significant abnormal performance"; according to his calculations, it was the strangest in 45 years. James Simons's Renaissance Technologies fund slid 8.7 percent in the first week of August, and in a letter to his investors, he called it a "most unusual period." As Andrew Lo put it, "Unfortunately, life has gotten very interesting." The *Wall Street Journal* called it an "August ambush."

The damage quickly spread beyond the market for low-quality debt instruments. It was almost as if the financial world had become a market for nothing so much as standard deviations, the mathematical term for the spread of values straying from a mean. In fact, the summer might be described as a time when too many investors had purchased standard deviations that were too high for their means.

Among the lessons that August taught is that there may be a finite number of viable investing strategies—a suspicion borne out by the oddly synchronous decline of many quant funds this summer, including Simons's Renaissance Technologies. August's bizarre market behavior, according to Rothman and others, was probably the product of some large hedge funds' seeking cash to meet their debt obligations, as the value of their CDOs declined, by selling those securities that were easiest to shed, chiefly stocks. (And which funds? In another example of the secrecy of fund managers, no one really seems to know, or wants to say.)

According to most of those to whom I spoke, something like the following occurred this summer. Quants had, in the ordinary nature of their jobs, "shorted" many stocks. Shorting is an arrangement whereby an investor borrows a stock from a broker, guaranteeing the loan with collateral assets placed in what is called a margin account. The investor straightaway sells the borrowed stock; if the stock then declines in value, the investor buys it back and pockets the difference in price when he returns the stock to the broker. But if the stock unexpectedly increases in value, even for a little while, the investor must either place additional collateral in the margin account to cover the difference or buy back the shorted stock and return it to the broker.

CDOs had functioned as the collateral on the quants' short positions. When the subprime crunch squeezed the financial markets, the value of those CDOs declined, forcing quants to increase the collateral in margin accounts, buy back the shorted stocks, or both. But in either case, in order to supplement their shrinking collateral, quant funds were forced to sell strong blue-chip stocks, whose prices consequently fell. At the same time, as quants bought back shorted stocks, the prices of *those* stocks increased, demanding the posting of yet more collateral to margin accounts at the very time that the value of CDOs was suffering. That the quants were, apparently, long on the same strong stocks and short on the same weak stocks was a result of a number of strategies, pairs trading among them.

Another related explanation for the August downturn was that the quants' models simply ceased to reflect reality as market conditions abruptly changed. After all, a trading algorithm is only as good as its model. Unfortunately for quants, the life span of an algorithm is getting shorter.

Before he was at RiskMetrics, Gregg Berman created commodity-trading systems at the Mint Investment Management Group. In the mid-1990s, he says, a good algorithm might trade successfully for three or four years. But the half-life of an algorithm's viability, he says, has been coming down, as more quants join the markets, as computers get faster and able to crunch more data, and as more data becomes available. Berman thinks two or three months might be the limit now, and he expects it to drop.

For Richard Bookstaber, a quant who has managed hedge funds and risk for companies like Salomon Brothers and Morgan Stanley, the August downturn proved that concerns he'd long harbored were well founded. Bookstaber was on the panel sponsored by the IAFE; in fact, he is everywhere these days. His book *A Demon of Our Own Design*, which appeared in April, was eight years in the making, and it made some very prescient predictions.

Bookstaber is a quiet, thoughtful man, with sharp brown eyes and an attentive look. He studied with Merton in the 1970s at MIT, where he got his doctorate in economics. Today, he is very worried about the tools and the methods of the quants. In particular, he frets about complexity and what he calls "tight coupling," an engineer's term for systems in which small errors can compound quickly, as they do in nuclear plants. The quants' tools, he feels, have became so complicated that they have escaped their creators. "We have gotten to the point where even professionals may not understand the instruments," he says. This, to Bookstaber, was perfectly demonstrated this summer, when the subprime troubles touched off a reactionary wave of selling in equities that would nominally seem unrelated, or, as Wall Street puts it, "uncorrelated."

"Nobody knew that what happened in the subprime market could affect what was going on in the quant equity funds," he says. "There's too much complexity, too much derivative innovation. These are the brightest people in the business. If it could happen to them, it could happen to anyone. No one could have predicted the linkage."

Linkage is one of Bookstaber's favorite topics. He believes that quants' instruments have "linked markets together that wouldn't normally be linked," and that such linkages are dangerous because they are unforeseen.

Berman and others I spoke to agreed with many of Bookstaber's concerns. "The products are getting an order of magnitude more complex," says Berman. "Things change slightly, and get correlated where they weren't correlated before." Or, as he put it a little less gnomically, "You can't make it without understanding it, but you *can* buy it."

Beneath all this beats the great hope of the quants: namely, that the financial world can be understood through math. They have tried to discover the underlying structures of financial markets, much as academics have unlocked the mysteries of the physical world. The more quants learn, however, the farther away a unified theory of finance seems. Human behavior, as manifested in the financial markets, simply resists quantification, at least for now.

Emanuel Derman remembers dreaming of such a unified financial theory in the early 1990s, a little after he had made the leap from the university to the Street. But those dreams, he says, are dead. Quantitative finance "superficially resembles physics," he says, "but the efficacy is very different. In physics, you can do things to 10 significant figures and get the right answer. In finance, you're lucky if you can tell up from down."

So up was down and down was up this summer, and Bookstaber and others hope it is a warning that will be heeded, rather than the beginning of a major systemic crisis.

And *was* subprime the canary in the mine? It was a question the panelists and the audience who showed up at Four World Financial Center last August are only beginning to answer. Leslie Rahl, for instance, cautiously told me in a follow-up e-mail that it is "looking more and more like the answer is yes." Many signs have suggested so, from job losses to a continuing credit drought to a weakening dollar, but that history has not yet been written.

The more quants learn, the farther away a unified theory of finance seems. Human behavior, as manifested in the financial markets, simply resists quantification, at least for now.

As a prelude to the panel discussion, Rahl asked the audience to predict whether credit spreads would shrink or widen in the coming months. She was talking about the difference between the price of a treasury bond and the price of a riskier corporate bond, a standard Wall Street gauge for the health of the economy. A widening credit spread is generally seen as a sign of uncertainty, and a narrow spread as a sign of optimism.

"How many think spreads will widen?" she asked.

The hands of about half the smartest people on Wall Street shot up.

"And how many think they'll narrow?"

The other half—equally smart—raised their hands.

"Well," she said. "That's what makes a market."

If they didn't know, nobody could. TR

Bryant Urstadt is a freelance writer based in New York. His work has appeared in Harper's *and* Rolling Stone.

MIT SLOAN EXECUTIVE EDUCATION.

Because All The Easy Problems Have Already Been Solved.

In a world of growing complexity, the traditional approaches to management that have shaped executive leadership for decades are no longer sufficient to run the modern organization. At the MIT Sloan School of Management, our programs combine technology, innovation, and leadership to provide senior executives and high-potential managers with the critical skills and practical tools needed to address today's complicated management challenges and lead successful organizations into the future.

Upcoming programs include:

Mar 30–Apr 4 Nov 9–14	**Managing the Extended Supply Chain:** Beyond Productivity and Efficiency *(in partnership with IMD)*
May 4–9	**Product Design, Development, and Management**
Jun 1–6	**Leading Change in Complex Organizations**
Jun 1–27	**International Management Program**
Jun 8–13	**Corporate Strategy**
Jun 16–20	**Business Dynamics:** MIT's Approach to Diagnosing and Solving Complex Business Problems

MIT Sloan Management

innovation@work™

http://mitsloan.mit.edu/tr

Phone: +1 617.253.7166 • Email: sloanexeced@mit.edu

What Is He Doing?

Evan Williams got rich when he sold Blogger to Google. Then he started Twitter. In both cases, he extracted a simple, obvious tool from a more complex, struggling technology. Is this guy lucky?

By Kate Greene
Photographs by Toby Burditt

When he was 16, Evan Williams loved reading business books. The first one he read was about real estate, and at the time, he lived in Clarks, a town in central Nebraska that today has a population of 379 and a median home value of $34,900. Williams wasn't particularly interested in investing in property in Clarks or anywhere else, but he reveled in the fact that it was so easy to learn about building businesses and making money. "I realized I could go buy books and learn something that people had spent years learning about," he recalls. "I was very intrigued with the idea that there's all this stuff out there to know that you could use to your advantage. It was written down in these books, and no one around me was using it."

Today, Williams is half a continent away from Clarks, in San Francisco; no longer just reading about business, he's the founder of Obvious, the Web-product development company that owns the popular microblogging service Twitter. At 35, without a college degree, he has become a bootstrapping, improvisational businessman whose decisions are influenced by what he describes as "hallucinogenic optimism."

Williams became mildly famous in Silicon Valley during the first dot-com boom, after he cofounded Blogger in 1999. Blogger made it very easy for people to publish their thoughts on the Web in personal weblogs, as blogs were known at the time. In 2003, Google acquired Blogger for a sum the entrepreneur declines to disclose (although he says it was less than the $50 million that Valleywag, a Silicon Valley gossip blog, has reported). It was, in any case, a significant amount: Williams worked at the Googleplex in Mountain View for a little more than a year before he left with the cash to conjure more winning ideas.

At first, he struggled to find something that would fully engage his energies. But Twitter seems to be it. The idea behind the service is simple: people compose 140-character updates about themselves, ostensibly answering the question "What are you doing?" Users can post their updates by text-messaging from cell phones, by logging on to the Twitter website, or by using desktop software such as instant-messaging tools. Messages (also known as twitters, twits, and tweets) can be private, sent only to friends or groups of friends, or they can appear on Twitter's home page for all to see. Twitter has been so successful that last April, Williams spun it out into its own company.

Twitter's headquarters is in South Park, a tiny San Francisco neighborhood south of Market Street that attracts a mixed crowd. During the week, hipsters sip coffee in cafés on South Park Street, a one-way path that bounds the oval park; homeless men guard shopping carts near the park's entrance; and entrepreneurs and computer programmers gather inside offices that line the green, trying to build the next big thing.

I visited Twitter's loftlike office to meet Williams on a warm July afternoon. He has a spare frame and a handsome face that retains a youthful softness, and he was wearing his standard outfit of plain white T-shirt and jeans. The simplicity that made Blogger so attractive to Google, he told me, is similarly driving Twitter's growth. Williams matter-of-factly described how the companies came about (both serendipitously) and explained what he sees as their appeal: they fill people's need to stay connected with one another.

By the largely noncommercial standards of social-networking startups, Twitter is a success. (Whether the company can become a profitable business is another matter, one much debated among those who follow the social-networking industry.) Twitter took off in March, around the time it won a Web Award for best blog at the South by Southwest Interactive Festival in Austin, TX. Since then, the number of registered Twitter users worldwide has been steadily rising.

WHAT ARE YOU DOING?
Users of Twitter answer that question *all day long*. Here is Twitter's inquisitor, Evan Williams. He's posing for his picture in a magazine.

Twitter doesn't reveal the actual numbers, but TwitDir.com, a third-party Twitter directory, estimates that there are nearly 500,000 public users, who allow their profiles and updates to be searched. In August, Twitter received about $5 million in funding, much of which came from Union Square Ventures, a New York venture capital fund. The company is in talks with Hollywood studios about using Twitter for promotional purposes, and MTV used the service to promote its annual Video Music Awards in September. Perhaps the biggest indicator of Twitter's success is the sudden appearance of "me-too" startups boasting that their services offer Twitter's features and more. (For a review of Twitter and its competitors, see "Trivial Pursuits," p. 80.)

According to Williams, Twitter is catching on for a simple reason: "It's social, and people are social animals." But Twitter is a different way to be social, he says. Though Twitter updates have elements of blog posts, instant messages, e-mails, and text messages, they're often shorter, can be broadcast more widely, and require no immediate response. "It's a no-brainer," Williams says. "People like other people. So hearing from them, and being able to express yourself to people you care about in a really simple way, is fun, and it can be addictive."

Williams himself can seem addicted to continuous self-exposure. One night last August, he twittered, "Having homemade Japanese dinner on the patio on an unusually moderate SF evening. Lovely." He's not alone in his addiction. That same night, a Twitter user named Itiswell posted, "I am having problems with the computer with missing software components." And *I* wrote, "Sense of accomplishment: never has my bathtub been this clean."

Some experts, including Elizabeth Lawley, director of the social-computing lab at the Rochester Institute of Technology, see such posting as a completely new form of communication. "Because it focuses on the minutiae, it's almost as if you're seeing a pixel of someone's life," Lawley says. "When you see all of those little pieces together, it gives a much richer portrait. With other forms of communication, we don't tend to share those everyday things, but the question 'What are you doing?' is exactly the thing that we ask people we care about. Otherwise we only get the big events, the things that are worth sending an e-mail about."

To others, of course, twitters seem banal, narcissistic, and excruciatingly dull. Detractors believe, too, that the company is doomed because it lacks a clear path to profitability. A comment on the popular blog TechCrunch combines both sentiments: "Twitter is a worthless app for the most self-absorbed among us. There is no money involved and it will be extremely hard to insert any sort of advertising. A pay model won't fly either because the mobile networks will just launch an application themselves if Twitter tries that path. Furthermore, most blogs are really boring (perhaps even my own). Twits are even worse. 'I ate a cheese sandwich.' Yawn. Fail."

The criticism doesn't seem to bother Williams, in part because he's heard it before. "Actually, listening to people talk about Twitter over the last few months, you hear that almost all the arguments against it are the exact same arguments that people had against Blogger," he says. "'Why would anyone want to do this?' 'It's pointless.' 'It's trivial.' 'It's self-aggrandizing bullshit.' 'It's not technically interesting.' 'There's nothing to it.' 'How is this different from X, Y, and Z that's existed for the past 10 years?'" Indeed, there were blogging tools available when Blogger was released, and others have emerged since—including TypePad from Six Apart, which offers more features. But none has the simple appeal of Blogger, and none is as easy to use. These were the reasons Blogger was such an important force in the blogging revolution.

At first, Williams doesn't seem the type to dedicate himself to changing human communications. He fits a certain Midwestern stereotype: he's a thoughtful man of relatively few words. But the trajectory of his life defies that stereotype; growing up in Clarks left him dissatisfied. "Not to bad-mouth it," he says. "It's just not like people are striving to be their best. Doing something that's different doesn't occur to people. Looking around me, I think I did not want to be like most of the people I saw. I was always looking for a way out, to be different, to be exceptional."

Williams enrolled at the University of Nebraska right after high school but dropped out after a little more than a year. He was in Lincoln in 1994, just as the Web was becoming a mass phenomenon. Guessing that the Internet would be important, he decided to build a product around it: a video that explained the ins and outs of using a command line to connect computers across the network.

The video made a profit, and Williams started a full-fledged Internet company, with a variety of ideas for businesses and products. ("It was when the Internet was new enough that you could just say you were an 'Internet company' and didn't have to be more specific," he says.) The company failed spectacularly. "It was sort of a train wreck in terms of management," he admits. "I had lots of ideas for things that were potentially interesting products, but I had no idea what I was doing, either in terms of managing a company or on the technology side. If we could have written software, we would have been in a better position. We tried to hire people who could write software, but I couldn't manage them, and they didn't know much about what they were doing." After a year or so, Williams fired his employees and shut the company down. In 1996, he moved to Northern California.

The late 1990s were heady for entrepreneurs in San Francisco, who worked long hours, racing to build the web-

sites that would make their fortunes. "It was a pretty wild time," recalls Meg Hourihan, Blogger's cofounder. "You'd finish coding some feature for a product at 10 o'clock at night and then walk over to the party next door for free food and drinks."

Hourihan, an English major with an aptitude for computers, was a technology consultant at the time, and she craved an entrepreneurial adventure. Meanwhile, Williams was becoming interested in collaboration software that helped people work on joint projects more effectively. In the summer of 1998, he and Hourihan both attended a networking event in San Francisco. "I ended up sitting down next to Ev and talking to him," Hourihan says. "Somehow we started talking about the Web and computers, and I felt like he was the first person I had met who saw the potential on the Web that I saw, that it was a life-changing thing."

They started dating but after two months decided they would be happier as business partners. In the fall of 1998 they began to work together on Pyra, a Web-based project-management application. The goal was to create an online "worktable" that would keep track of project changes, questions, meetings, and more. The Pyra team became a company called Pyra Labs when a friend of Williams's from Nebraska, Paul Bausch, joined to help write the code. In order to keep tabs on the status of Pyra's features, the three employees posted updates on an internal blog they called "Stuff." Both Williams and Hourihan had been early bloggers, so it seemed a natural way to communicate. Stuff became the central nervous system for the company. "That was really how we communicated and collaborated, which is ironic because we were building this collaboration tool that was much more complex," Williams recalls. "We joked semiseriously many times that we should just make Stuff our product. I had a little bit of a thought that there was something to it, but it was just so ultrasimple that I didn't seriously consider it."

Then a slight modification to Stuff made Williams reconsider. One day, Bausch wrote a piece of code that made it possible to transfer an entry from Stuff to Pyra's public Web server using something called a file transfer protocol, or FTP; the entry would then be visible to anyone. "That was really the genesis of Blogger," Williams says. "The simplicity of having an application that ran on the Web that would then FTP a static file to your server was the key thing. Once we did that, we thought people would use that."

Eventually, it became clear that Blogger, not the more complex Pyra, was what people wanted: Williams had found a simpler, more valuable communications product inside the more diffuse company. The team raised money in a small round of funding. Yet Williams's colleagues were nervous because Blogger was a free service, and it still didn't have a business plan. And Williams, who was the CEO, struggled to raise more funds. "We started running out of money," says Hourihan. "We couldn't stay ahead of the infrastructure we needed to keep growing. Then the market collapsed, and it seemed like we couldn't raise another round."

The team, which had grown to six, bitterly disbanded. Williams "just took the servers back to his house and kept it going, a one-man show, for a while," says Hourihan. "Then things started to come back, and he was able to hire some people back and slowly get its legs under it again." Hourihan stayed away, but Williams was successful enough to negotiate the sale to Google in early 2003.

> "Actually, listening to people talk about Twitter over the last few months, you hear that almost all the arguments against it are the exact same arguments that people had against Blogger. 'Why would anyone want to do this?'"

After leaving Google, Williams took time off to find startup ideas. Instead, a startup found him. A friend, Noah Glass, was working on software to help people create, distribute, and search for podcasts, and he and Williams began to talk about the product. Williams started spending his days advising Glass, and eventually he invested in the new company, Odeo. At first, Williams wanted to maintain his distance in order to pursue other projects, but in February 2005, he was asked to unveil Odeo at TED, the yearly, invitation-only conference of technology, entertainment, and design. At TED, his name quickly got attached to the company. "I sort of had an ego thing going on where I was like, 'This is my next thing.' But that wasn't my intention in the beginning," he says. "I was excited and glad to help out, but I wasn't ready to start a new thing, and it wouldn't have been that." There was a lot of excitement surrounding Odeo, Williams recalls, and he got caught up in it, against his better judgment.

Odeo had plenty of funding up front (after Blogger, it wasn't hard for Williams to attract investors), but the company's prospects weren't really very healthy. No one had a clear sense of what its main product would be, and in June 2005, Apple released a version of iTunes, its audio software, that offered podcasting functions nearly identical to those Odeo was developing. "It sort of shocked us," Williams says. "Apple did it all, and they're on millions of desktops.


He's vacuuming the rug.


He's still vacuuming the rug.

All this stuff that we built was kind of irrelevant once Apple launched their product."

The problem wasn't just Apple's beating Odeo to market, he adds. Odeo's product demanded a more traditional approach to the media business, one that relied on distribution and media deals as opposed to viral growth, and that wasn't the type of business model that appealed to Williams and the company's engineers. "We just weren't a company that was going to excel in those things," Williams says. Realizing this, he went to the board in October 2006 and bought the company with his Google money. Among Odeo's assets was an early version of Twitter—at the time, merely a side project.

Liz Lawley of the Rochester Institute of Technology was initially skeptical of Twitter when she started using it in February. "My first reaction was that I don't need another place to post things, yet another user name and password to remember," she says. "I have four blogs, and it didn't seem to me that I needed to do anything different." But by March, she was twittering on a regular basis. Now she tends to twitter mainly when she's traveling, when something unusual is happening, or when a lot is going on in her life. "It's easier to update people that way rather than figuring out who to send e-mails to," she says.

Lawley represents only one type of Twitter user. Some people are hypergraphic, posting incessantly. Others rarely post but follow the updates of people they don't know. A few writers are experimenting to see how storytelling changes when it's produced in 140-character increments, while others are creating charming haikus. People are also using Twitter to send clues for scavenger hunts and other games. And individuals aren't the only users. In fact, the service has proved useful for advertisers, news outlets, and even fire departments.

These uses aren't surprising to Jack Dorsey, the Odeo engineer who proposed Twitter to Williams in 2006. Dorsey, now Twitter's CEO, had always been fascinated with real-time communications and dispatching systems—the kind that send taxis around cities and ensure that ambulances quickly

He's thinking *and* vacuuming the rug.

He's finished vacuuming the rug!

arrive at the right place. "Back in February of 2006, we were having a bunch of conversations about how to change Odeo into something that we loved," he recalls. "We wanted something a little bit different. Texting was getting big, and in a meeting I brought up the idea of Twitter. It was the simplest thing we could do: send what you're doing to your friends, and that was it. Everyone started thinking about that, and a week later Evan gave me the go-ahead to build a prototype."

Just like Blogger, Twitter was a simple communications product salvaged from the impending implosion of a more complex project. In both cases, Williams didn't really know what he was doing. With both ventures, his genius—if that is the word—derived from what the English poet John Keats, in a letter to his brothers, called "negative capability": "that is when man is capable of being in uncertainties, Mysteries, doubts without any irritable reaching after fact & reason."

With the help of another engineer, Dorsey built the basics of Twitter in about two weeks, using a popular Web programming framework called Ruby on Rails. At Twitter's core is a simple messaging distribution machine that is, in the jargon of communications, "device agnostic." After a twitterer composes a 140-character update and clicks a button on a Web page, in an instant-messaging program, or on a cell phone, the tweet is almost instantaneously routed to the people who have elected to receive it. They in turn will read the message on the Web, with an instant-messaging program, or on a cell phone, according to their preferences.

Crucial to Twitter's popularity was the release in September 2006 of its application programming interface, or API, which allows outside programmers to build applications that plug into the company's information infrastructure. Once the API was available, geeks everywhere started to create innovative Twitter tools. "A ton of our usage is through our API," says Williams. And the API is relatively simple: "It's not the most powerful development framework, but it's encouraged a ton of people to play with it. This means that a ton of interfaces and tools were built and plugged into Twitter because of that simplicity."

Among the tools that third-party developers have built are desktop interfaces. An example is Twitterrific, a down-

loadable program for Macs, which makes twitters pop up on the Mac OS desktop and then fade into the background. Another way people have tapped into Twitter's code is by redisplaying the public posts in interesting ways: in a program called Twittervision, for example, a globe displays twitters as they are posted all around the world. It is the diverting spectacle of the human race (or at least that part of it that twitters) talking to itself. Bots—automated program—can also post twitters with content extracted from some information feed. There are news and weather bots, and little programs that update users with earthquake information from the U.S. Geological Survey.

By letting programmers build twittering tools that appeal to a broad range of people, Twitter has gained many more users. And this could be just the beginning. "Another way to look at it is as a platform for device-agnostic real-time messaging," Williams says. "And that has broader implications. People have contacted us about emergency broadcasting systems. We like the idea, but we're not anywhere near saying that we want to be counted on for that." For emergency use, Twitter would need to be reliable, a goal that seems elusive. This past summer saw many Twitter outages, both planned and unscheduled, and it's not uncommon to have a twitter or two dropped.

Williams, Dorsey, and another Twitter cofounder, Biz Stone, are betting that by shoring up the service's infrastructure, they'll be able to fend off the mounting ranks of competitors. These include Jaiku, Plazes, Kyte, Yappd, Pownce, and Facebook (which has a feature that lets users update their "status" in a way that resembles twittering). All of these services differ: Jaiku has more functions than Twitter—users can add pictures to their posts, for instance—but it's a bit complicated to use, and it doesn't yet have as many users as Twitter. Pownce, which is still in its beta-testing phase, allows invited users to share different types of files with different groups of people: users can create lists that allow them to send information to one person (as in an instant message), to a few of their contacts, or to all of them. And Facebook is "in a much stronger position" than Twitter, Williams says, because for social applications, the number of users is crucial.

"If you look at Pownce and Twitter and Facebook today, they're all conceptually the same, but they'll evolve in different ways," Williams says. "We know there are lots of features and functionality that we want to add and will add, but we don't want to make it more complicated, because we do think that much of the beauty is in simplicity."

Staying static for too long on the Web is risky, however, especially for the first company with a new type of technology. In 2002, a social-networking site called Friendster quickly became successful, gaining droves of users who created profiles that linked to their friends'. Friendster's social-networking preëminence didn't last long: in 2003, MySpace entered the picture. Now MySpace, which is owned by Rupert Murdoch, has around 100 million registered users, and it's growing. Friendster still operates, but at a smaller scale than MySpace. (See "Friend Spam," by Friendster founder Jonathan Abrams, on p. 24.)

Williams says that he thinks about Friendster's fate, especially when Twitter's service falters. "We're doing okay now, but when we were doing really poorly, the Friendster analogy came up," he says. This is why it's crucial to focus on improving reliability and making the interface even more foolproof, he adds. "I think if we can make it perform and make it obvious how to use it and just get it in front of people, we'll do well."

> Williams's genius—if that is the word—derived from what the poet John Keats, in a letter to his brothers, called "negative capability": "that is when man is capable of being in uncertainties, Mysteries, doubts without any irritable reaching after fact & reason."

Williams believes that building a healthy infrastructure is also the key to eventually making a profit, so that's what he hopes to do with the money from Union Square Ventures. Fred Wilson, a Union Square managing partner, says, "I think with a lot of these kinds of services, the big looming question is 'How are we going to make money?' In the case of Twitter, we felt if they could build a communication system that was easy to use and was used in lots of different ways by lots of different services, then they could become a piece of the infrastructure of the Internet." At that point, Twitter would possess enough "messaging volume" to get paid by someone: "probably by other people who want to participate in that volume—maybe wireless carriers," Wilson speculates.

"Our advice was to not focus on generating revenue on day one," he adds, "but focus on getting as many people and as many services as you can to use the underlying Twitter infrastructure to build messaging services."

Crucial to this plan is ensuring that Twitter's technology—that is, the structure of the system's underlying code—can support new users as they join the service. Technologists say that a network "scales" when it can take on an increasing number of customers. A good portion of the company's

recent funding, Williams and Wilson say, will go toward making Twitter "scalable." If that doesn't happen, opportunities for profit may go unrealized.

When I last saw Williams, he had just returned from his honeymoon, a safari in Kenya. (In Africa, predictably, he twittered using his cell phone: "Touring Nairobi." "Having drinks after a day of game drives and relaxing." "Watching lions. Shhh.") Over breakfast at a restaurant in San Francisco's Mission District, he told me that he's taking a few steps back from Twitter: he'll sit on the company's board but leave coding to the engineers and the day-to-day management to Dorsey. Before his wedding, Williams explained, he had spent a lot of time writing code for features and slogging through the daily maintenance of the service. Now he feels the company is in capable hands without him.

So do his venture capitalists, it turns out. Williams "seems a little more thoughtful and willing to live with ambiguity more than most of the entrepreneurs I know," says Fred Wilson. "That's a big positive, but it could be a big negative, too. It's a positive because startups need to have ambiguity around for a while, but a lot of the time things need to be decided, which is why I think it's good he's letting Jack [Dorsey] run the company. Jack is probably a little more decisive."

Now Williams says he wants to work more on Obvious, which, for him, is a different type of venture; he describes it as a kind of incubator for products that solve obvious problems. Obvious (which upon its founding in October 2006 absorbed Odeo) wasn't created with a product or even a technology in mind; it was conceived as a company where ideas are fueled until they either catch fire or simply fade away. But as of our meeting, Williams was the only employee, and it's clear that he doesn't know how Obvious will operate.

Williams has some technological problems he'd like to explore, including his old preoccupation at Pyra: the question of how companies can communicate more effectively, both internally and with other companies. He has at least one person in mind to do some coding, too. Still, he seems uncertain how any solution could be turned into a product, let alone a viable business.

In fact, he tells me, he doesn't have any solid plans. At the end of 2007, Williams finds himself in the same state that he has so often been in before: uncertain, without any irritable reaching after fact and reason. TR

Kate Greene is Technology Review*'s information technology and computer science editor.*


RIPPING & REP
IS SO OLD

It's time to move to the future with the hardware you've got.

When moving to VoIP, ripping and replacing used to be the only way. Now, it's the out-of-date way. That's because it's no longer about hardware.

It's actually about software.

Now you can keep your hardware—your PBX, your gateways, even your phones. Simply move to VoIP with software. Software that integrates with Active Directory,® Microsoft® Office, Microsoft Exchange Server, and your PBX.

Maximize your current PBX investment and make it part of your new software-based VoIP solution from Microsoft. You're much closer to VoIP than you realize. Learn more at microsoft.com/voip

VOIP AS YOU ARE.

Your potential. Our passion.®

Microsoft®

Measuring the Polar Meltdown

At a remote outpost in northern Greenland, an international team of scientists is attempting to resolve the critical mystery of global warming: how quickly will sea levels rise?

By David Talbot

ON THE EDGE: **Tourists scramble over the melting edge of Greenland's ice sheet near the town of Kangerlussuaq. The rate at which some glaciers are sliding into the ocean has doubled or more in a decade, outpacing estimates that inform official predictions of sea-level rise.**

DAVID TALBOT

From the air, the western edge of Greenland's ice sheet looks like an aging elephant's skin—gray and cracked, as melting at the margins exposes dirt accumulated over tens of thousands of years. A few kilometers inland, however, the gray gives way to blazing white that goes on for hundreds of miles. These vast glaciers contain snow that has fallen and compacted over millennia. The ice sheet—roughly four times the size of California, and more than three kilometers thick in places—is, in essence, a vast frozen reservoir of fresh water.

About 300 kilometers from the coast, high above the Arctic Circle, is the newest polar science station in Greenland, comprising two tents, a hut, two sledge-mounted domes, and a few vehicles. The only way to describe the location is by GPS coördinates: 77°26'54.92885" N, 51°3'19.89396" W. The station sits atop 2,500 meters of ice.

The modest encampment, manned by a nine-person scientific and support crew from a Danish-led international team, might be in the middle of nowhere, but it is also at the center of a growing effort to answer the crucial question of global warming: how quickly, and by how much, will sea levels rise? The two great polar land masses, Greenland and Antarctica, together hold nearly 99 percent of the planet's landlocked ice, which is capable of raising sea levels when it melts (the melting of sea ice, such as that floating in the Arctic, does not raise the level of the oceans). The giant ice sheets hold enough frozen water to raise sea levels some 80 meters.

If only 10 percent of this ice melted, it would flood the world's coasts at levels comparable to those seen in post-Katrina New Orleans. While nobody is predicting a catastrophe on that scale anytime soon, scientists are concerned that melting might greatly accelerate as the planet warms. Especially worrisome is a scenario that glaciologists and climate scientists are still piecing together: rather than slowly but steadily melting, the ice sheets could rapidly break apart. Recent observations show that some of the major glaciers on Greenland and the West Antarctic Ice Sheet are sliding ever faster seaward. But the processes involved are not well enough understood to be incorporated into the computer models used to predict how much sea levels will rise in response to climate change.

Gauging the risk that the ice sheets will break apart—and estimating how fast such a breakup would raise sea levels—will require a far better understanding of geology. Not all the bedrock beneath Greenland and Antarctica is mapped. Nobody knows how much liquid water lies under the ice; even a small amount could dramatically speed the breakup of the ice sheets by making the surface below them much more slippery. Across both land masses, scientists are striving to make more precise measurements. Some are busy installing GPS stations on the ice sheets and the bedrock surrounding the coasts to more accurately calcu-

late loss of ice mass. Others are measuring snowfall accumulation and studying how snow compacts into ice. In this way, they are trying to estimate just how much inland ice there is—and by extension, how much has fallen into the ocean.

"We need to go right back to the drawing board on what the ice sheets are about," says Ted Scambos, lead scientist at the National Snow and Ice Data Center at the University of Colorado at Boulder. "Fifteen years ago, we thought ice sheets wouldn't respond quickly to global warming because the melting would happen at the surface. This was true, but what we didn't count on was fracturing. This permits water to get to the base of the ice, all the way through the ice sheet. We were really surprised to see this even where the ice core is well below freezing. The water allows glaciers to flow more rapidly, dumping the ice into the sea."

DRILL SERGEANT: **Jørgen P. Steffensen (top left), a glaciologist at the University of Copenhagen, is co-leader of a quest to find and study ancient ice from a period when sea levels surged. Claude Laird of the University of Kansas (bottom left) stands with Lars Berg Larsen of the University of Copenhagen near a pole marking a new ice-coring site in northern Greenland. Signs of melting are obvious on the edge of Greenland's giant ice sheet (right).**

DAVID TALBOT

A Mystery

The Intergovernmental Panel on Climate Change (IPCC), the international panel of scientists that weighs in every five years or so on the state of the climate, predicted earlier this year that seas would rise between 18 and 59 centimeters this century. While the higher figure is quite worrisome in low-lying coastal areas, the numbers are still small enough—and the prospect far enough in the future—to seem manageable for most of the world. But the IPCC, in explaining its numbers, added that it could provide neither a "best estimate" nor an "upper bound" for how much higher sea levels might rise if the ice sheets disintegrate. *(See "Sea-Level Riddle," p. 25.)*

Indeed, the IPCC's sea-level estimates are based on math that takes into account only a few well-understood processes. One is the expansion of seawater as it warms. Another is the melting of mountain glaciers in temperate zones—places like the Alps, Andes, and Himalayas. Third is the melting of the ice sheets' surfaces and the glaciers' seaward migration under the pull of gravity, though this may be partly balanced by increased snowfall that occurs because warmer air holds more moisture. The problem is that other processes may actually prove far more consequential. Warmer and higher oceans undermine the glaciers that flank Greenland and Antarctica, yanking them away from their seabed moorings. With those bulwarks weakened, inland glaciers slide much faster toward the sea. In a complementary process, water gushes down through fractures and holes in the Greenland ice sheet, making it easier for its glaciers to slide. As the glaciers reach lower (and therefore warmer) elevations, the melting and sliding will further accelerate.

And that's exactly what appears to be happening. Recent observations have shown that the movement of major glaciers in both Greenland and the West Antarctic Ice Sheet is in fact accelerating. To pick just two examples, by 2005 a vast glacier in Greenland, the Jakobshavn, was slipping seaward twice as fast as it had in 1996, and another, the Kangerdlugssuaq, was slipping three times as fast as it had in 2000. "The cur-

In less than a decade, two vast Greenland glaciers–the Jakobshavn and Kangerdlugssuaq–started slipping seaward two and three times faster. Computer models didn't see it coming.

rent dynamical changes that we are seeing on the ice sheet are not captured in any climate model," says Prasad Gogineni, director of the Center for Remote Sensing of Ice Sheets at the University of Kansas, which is a participant in the Danish-led effort. "That seems to indicate a huge uncertainty." Today's climate models, he says, simply can't be relied on to predict what will happen to the great ice sheets.

Greenland's melting ice sheet is now contributing more than half a millimeter per year to sea-level rise, according to a study coauthored by Eric Rignot, a senior research scientist at NASA's Jet Propulsion Laboratory who has collaborated with Gogineni and others at the University of Kansas. That seemingly small figure is noteworthy because it's more than twice the upper limit of Greenland's contribution as estimated by the IPCC in its report earlier this year. "The [existing models] don't assume any change in velocity in the glaciers, except on very long time scales," Rignot says. "What we are seeing today is that those glaciers do speed up in a significant fashion in response to climate warming."

The melting of the ice sheets is really just getting started, says Rignot. The current surge in the velocity of the glaciers has accompanied the 0.74 °C of warming the planet has seen over the past 100 years. The IPCC is predicting that global temperatures will rise far more in the next 100 years–1.8 °C to 4 °C, depending on future emissions of greenhouse gases. The resulting loss of ice will dwarf any increases in snowfall, Rignot says. But Rignot disagrees with the conclusions drawn by the IPCC: he believes oceans will rise more than a full meter before the end of the century, nearly twice the upper bound of the IPCC's predictions. "We have to acknowledge that we don't have reliable ways to predict what ice sheets will do, but that they will certainly react much more strongly to climate warming in the future," he says. "There is no reason to alarm people that the end of the world is coming. But there is no reason to reassure them, either, that there is nothing to worry about with the ice sheets."

Drilling Down

With advanced radar technology, researchers at the north Greenland site are producing the first detailed pictures of large areas of the ice-sheet base, with particular attention to pockets of water. Previous technology could detect large

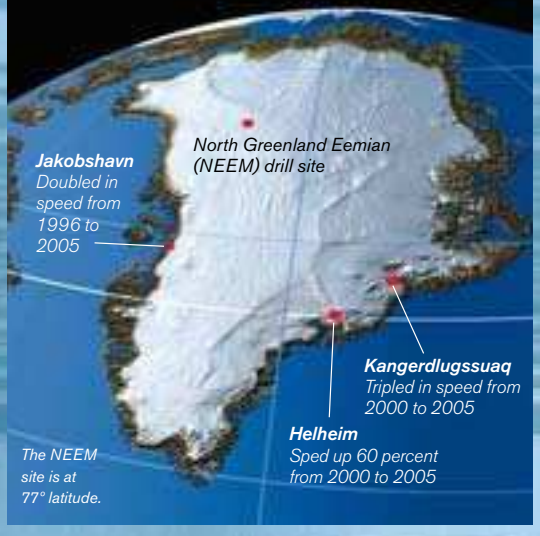
Quest for Ancient Ice

To understand how quickly ice sheets will deteriorate, thereby raising sea levels, scientists want to know more about the Eemian interglacial, a period of geologic history between 130,000 and 115,000 years ago. During that period, eccentricities in Earth's orbit caused Greenland's temperatures to jump 7 to 8 °C, and sea levels rose at least three to five meters higher than they are now. Surviving Eemian ice would contain a trove of information about the temperatures and atmospheric conditions of the time. But ice from the entire Eemian has never been recovered in Greenland. Using advanced radar, scientists this year chose a new spot to seek it.

A team of scientists plans to return next summer to an encampment in northern Greenland and drill down 2,500 meters (red line) through the ice cap to search for Eemian ice.

Accelerating Glacier Loss

Across southern Greenland, vast glaciers—including the three shown below—have been flowing toward the sea much faster in recent years. By trying to understand the underlying processes, scientists hope to improve predictions of sea-level rise.



Deep ice layers—invisible to the naked eye—become visible thanks to advanced radar and postprocessing software. The layers represent changes in the electrical conductivity of the ice, which are primarily due to increased acidity from past volcanic activity. Seeing such layers can help scientists tell whether ice from a particular period is intact or distorted by glacial movements or melting.

Scientists believe that a 120-meter-thick chunk of ice, from near the bottom of the 2,500-meter-thick ice sheet, may contain intact ice from the entire Eemian period.

JOHN MACNEILL

lakes underneath the ice. But the new technology, honed at the University of Kansas and deployed by researchers from both Kansas and the University of Copenhagen, can detect even a few millimeters of water, which are just as dangerous. What's more, whereas previous radar equipment took measurements only of the ice directly beneath it, the new technology also provides information about ice layers and the ice sheet's base in a three-kilometer-wide swath of ice cap.

During the winter of 2005–2006—summer in Antarctica—scientists from Kansas lugged the new system down to the West Antarctic Ice Sheet and collected data on a 30-by-10-kilometer grid. Early results show much more detail about which parts of the ice sheet's base are sitting on water and which are still frozen to the ground. Whether the water came from geothermal heat, friction from ice in motion, or accumulation of surface meltwater is not yet clear. But the new data should help improve ice-sheet models, says Claude Laird, a research scientist at the University of Kansas and a member of both the Antarctic and the north Greenland expeditions. This summer, Laird and the other scientists used the technology to map a 370-kilometer swath of Greenland. When the results start coming in, they should give a clear picture of that swath, and of how much water lies within the ice or beneath the sheet.

Meanwhile, the scientists are seeking clues from the past. At the north Greenland base station, amid the huts and vehicles, an aluminum pole is staked to the ice cap. Next summer, the scientists will return to the spot and start drilling out an ice core, boring about 2,500 meters to bedrock. They are particularly interested in one key geologic period, called the Eemian interglacial. During this stretch of time, from around 130,000 to 115,000 years ago, the planet warmed. Greenland hit temperatures 7 to 8 °C warmer than today's, and sea levels surged at least three to five meters higher than they are now. If this happened today, much of south Florida, Bangladesh, and many other low-lying coastal areas and islands would be submerged.

The warming during the Eemian period was caused by eccentricities in Earth's orbit that periodically allow more solar energy to hit the planet. An understanding of how the climate and ice sheets responded during the Eemian warm-up should sharpen our picture of how they'll respond today. Already, a record of Eemian sea levels is available from existing geological sites. But scientists would like to know more about short-term climatic variations—coolings and warmings—within the Eemian period. That should help them better understand current climate changes and more accurately predict how sea levels will rise.

Glaciers accrete over time, and different layers contain records of Earth's past climate. A sample of ice spanning the whole Eemian period—never before found in the northern hemisphere—would provide a wealth of information. Identifying oxygen isotopes within water molecules can reveal what temperatures prevailed when snow fell. Trapped air bubbles inside ice contain samples of the old atmosphere. The thickness of ice layers can reveal how much snow fell. And bits of dust and organic matter will allow accurate dating. After conducting radar analysis, the researchers at north Greenland think the spot marked by the aluminum pole—dubbed NEEM, for "North Greenland Eemian"—will contain a 120-meter-thick chunk of ice representing the entire period *(see "Quest for Ancient Ice," opposite)*. "We can get even better data on these fast climate oscillations," says Laird. "And we can get some forecasting about what climate change will mean."

Stuck

In north Greenland, the science is done for the season. It had taken the team of scientists nine days to reach the site—a 370-kilometer slog, dragging thousands of kilograms of equipment, fuel, and food and using two snowcats, three snowmobiles, and a Toyota Land Cruiser outfitted with tracks. Their trip was plagued by delays: at one point, a blizzard had them hunkering down for days; at another, two of the Land Cruiser's tracks broke. After more than four weeks in the field, the scientists waited to be evacuated. Though it was only August, dangerous weather loomed, and they were anxious to get home and analyze data they'd gathered during their weeks of work.

But first they had to get off the ice sheet. On a sunny afternoon—with temperatures reaching –4 °C—a ski-equipped cargo plane made a soft touchdown. After disembarking, the pilot, in his olive-green jumpsuit and wraparound sunglasses, kicked worriedly at a new layer of snow.

Three hours later, the nine scientists and crew members had boarded the cargo plane. The plane labored up and down the snowy runway. But just as the pilot had feared, the snow was too soft for the plane to reach takeoff speed. Departure would need to wait 12 hours, until 4:00 A.M., the coldest time of day. At the appointed hour, they tried again. This time, ice was frozen to the bottom of the plane's front ski. The pilot's efforts to shake it loose, using hydraulics to move the ski up and down against the snow, broke a pin that held the hydraulics in place. Another plane needed to deliver the replacement parts.

Finally, around 11:00 P.M. that night, a second cargo plane landed. It was nearly 20 °C below zero. A crew from the second plane sprinted across the ice, fixed the ski, and took off again with a rocket-assisted flourish. And finally, the original plane followed suit, skating quickly across the icy surface. Amid the roar of side-mounted rocket motors, the researchers and the crew made it aloft at 2:30 A.M., a day and a half after their first try. Fortunately, the ice sheet was frozen solid. For now. TR

David Talbot is Technology Review*'s chief correspondent.*

Fiction

Steve Fever

Countless tiny machines hijack the living, borrowing their hands, eyes, and ears, as the machines strive to resurrect just one man.

By Greg Egan

Illustrations by Justin Wood

A few weeks after his 14th birthday, with the soybean harvest fast approaching, Lincoln began having vivid dreams of leaving the farm and heading for the city. Night after night, he pictured himself gathering supplies, trudging down to the highway, and hitching his way to Atlanta. ¶ There were problems with the way things got done in the dream, though, and each night in his sleep he struggled to resolve them. The larder would be locked, of course, so he dreamed up a side plot about collecting a stash of suitable tools for breaking in. There were sensors all along the farm's perimeter, so he dreamed about different ways of avoiding or disabling them.

Even when he had a scenario that seemed to make sense, daylight revealed further flaws. The grille that blocked the covered part of the irrigation ditch that ran beneath the fence was too strong to be snipped away with bolt cutters, and the welding torch had a biometric lock.

When the harvest began, Lincoln contrived to get a large stone caught in the combine, and then volunteered to repair the damage. With his father looking on, he did a meticulous job, and when he received the expected praise he replied with what he hoped was a dignified mixture of pride and bemusement, "I'm not a kid anymore. I can handle the torch."

"Yeah." His father seemed embarrassed for a moment. Then he squatted down, put the torch into supervisor mode, and added Lincoln's touch to the authorized list.

Lincoln waited for a moonless night. The dream kept repeating itself, thrashing impatiently against his skull, desperate to be made real.

When the night arrived and he left his room, barefoot in the darkness, he felt he was finally enacting some long-rehearsed performance—less a play than an elaborate dance that had seeped into every muscle in his body. First he carried his boots to the back door and left them by the step. Then he took his backpack to the larder, the borrowed tools in different pockets so they wouldn't clank against each other. The larder door's hinges were attached on the inside, but he'd marked their positions with penknife scratches in the varnish and practiced finding the scratches by touch. His mother had secured the food store years before, after a midnight raid by Lincoln and his younger brother, Sam, but it was still just a larder, not a jewel safe, and the awl bit through the wood easily enough, finally exposing the tip of one of the screws that held the hinges in place. The pliers he tried first couldn't grip the screw tightly enough to get it turning, but Lincoln had dreamed of an alternative. With the awl, he cleared away a little more wood, then jammed a small hexagonal nut onto the screw's thread and used a T-handled socket wrench to turn them together. The screw couldn't move far, but this was enough to loosen it. He removed the nut and used the pliers. With a few firm taps from a hammer, delivered via the socket wrench, the screw broke free of the wood.

He repeated the procedure five more times, freeing the hinges completely, and then strained against the door, keeping a firm grip on the handle, until the tongue of the lock slipped from its groove.

The larder was pitch black, but he didn't risk using his flashlight; he found what he wanted by memory and touch, filling the backpack with enough provisions for a week. *After that?* He'd never wondered, in the dream. Maybe he'd find new friends in Atlanta who'd help him. The idea struck a chord, as if it were a truth he was remembering, not a hopeful speculation.


WELCOME TO
wonderful

The toolshed was locked securely, but Lincoln was still skinny enough to crawl through the hole in the back wall; it had been hidden by junk for so long that it had fallen off the end of his father's repair list. This time he risked the flashlight and walked straight to the welding torch, rather than groping his way across the darkness. He maneuvered it through the hole and didn't bother rearranging the rotting timbers that had concealed the entrance. There was no point covering his tracks. He would be missed within minutes of his parents' rising, no matter what, so the important thing now was speed.

He put on his boots and headed for the irrigation ditch. Their German shepherd, Melville, trotted up and started licking Lincoln's hand. Lincoln stopped and petted him for a few seconds, then firmly ordered him back toward the house. The dog made a soft, wistful sound but complied.

Twenty meters from the perimeter fence, Lincoln climbed into the ditch. The enclosed section was still a few meters away, but he crouched down immediately, practicing the necessary constrained gait and shielding himself from the sensors' gaze. He clutched the torch under one arm, careful to keep it dry. The chill of the water didn't much bother him; his boots grew heavy, but he didn't know what the ditch concealed, and he'd rather have waterlogged boots than a rusty scrap of metal slicing his foot.

He entered the enclosed concrete cylinder; then a few steps brought him to the metal grille. He switched on the torch and oriented himself by the light of its control panel. When he put on the goggles he was blind, but then he squeezed the trigger of the torch, and the arc lit up the tunnel around him.

Each bar took just seconds to cut, but there were a lot of them. In the confined space the heat was oppressive; his T-shirt was soon soaked with sweat. Still, he had fresh clothes in his pack, and he could wash in the ditch once he was through. If he was still not respectable enough to get a ride, he'd walk to Atlanta.

"Young man, get out of there immediately."

Lincoln shut off the arc. The voice, and those words, could only belong to his grandmother. For a few pounding heartbeats, he wondered if he'd imagined it, but then in the same unmistakable tone, ratcheted up a notch, she added, "Don't play games with me—I don't have the patience for it."

Lincoln slumped in the darkness, disbelieving. He'd dreamed his way through every detail, past every obstacle. How could she appear out of nowhere and ruin everything?

There wasn't room to turn around, so he crawled backward to the mouth of the tunnel. His grandmother was standing on the bank of the ditch.

"What exactly do you think you're doing?" she demanded.

He said, "I need to get to Atlanta."

"Atlanta? All by yourself, in the middle of the night? What happened? You got a craving for some special kind of food we're not providing here?"

Lincoln scowled at her sarcasm but knew better than to answer back. "I've been dreaming about it," he said, as if that explained everything. "Night after night. Working out the best way to do it."

His grandmother said nothing for a while, and when Lincoln realized that he'd shocked her into silence he felt a pang of fear himself.

She said, "You have no earthly reason to run away. Is someone beating you? Is someone treating you badly?"

"No, ma'am."

"So *why exactly is it* that you need to go?"

Lincoln felt his face grow hot with shame. How could he have missed it? How could he have fooled himself into believing that the obsession was his own? But even as he berated himself for his stupidity, his longing for the journey remained.

"You've got the fever, haven't you? You know where those kind of dreams come from: nanospam throwing a party in your brain. Ten billion idiot robots playing a game called Steve at Home."

She reached down and helped him out of the ditch. The thought crossed Lincoln's mind that he could probably overpower her, but then he recoiled from the idea in disgust. He sat down on the grass and put his head in his hands.

"Are you going to lock me up?" he asked.

"Nobody's turning anybody into a prisoner. Let's go talk to your parents. They're going to be thrilled."

The four of them sat in the kitchen. Lincoln kept quiet and let the others argue, too ashamed to offer any opinions of his own. How could he have let himself sleepwalk like that? Plotting and scheming for weeks, growing ever prouder of his own ingenuity, but doing it all at the bidding of the world's stupidest, most despised dead man.

He still yearned to go to Atlanta. He itched to bolt from the room, scale the fence, and jog all the way to the highway. He could see the whole sequence in his mind's eye; he was already thinking through the flaws in the plan and hunting for ways to correct them.

He banged his head against the table. "Make it stop! Get them out of me!"

His mother put an arm around his shoulders. "You know we can't wave a magic wand and get rid of them. You've got the latest counterware. All we can do is send a sample to be analyzed, do our bit to speed the process along."

The cure could be months away, or years. Lincoln moaned pitifully. "Then lock me up! Put me in the basement!"

His father wiped a glistening streak of sweat from his forehead. "That's not going to happen. If I have to be beside you everywhere you go, we're still going to treat you like a human being." His voice was strained, caught somewhere between fear and defiance.

Silence descended. Lincoln closed his eyes. Then his grandmother spoke.

"Maybe the best way to deal with this is to let him scratch his damned itch."

"What?" His father was incredulous.

"He wants to go to Atlanta. I can go with him."

"*The Stevelets* want him in Atlanta," his father replied.

"They're not going to harm him—they just want to borrow him. And like it or not, they've already done that. Maybe the quickest way to get them to move on is to satisfy them."

Lincoln's father said, "You know they can't be satisfied."

"Not completely. But every path they take has its dead end, and the sooner they find this one, the sooner they'll stop bothering him."

His mother said, "If we keep him here, that's a dead end for them too. If they want him in Atlanta, and he's not in Atlanta—"

"They won't give up that easily," his grandmother replied. "If we're not going to lock him up and throw away the key, they're not going to take a few setbacks and delays as some kind of proof that Atlanta's beyond all hope."

Silence again. Lincoln opened his eyes. His father addressed Lincoln's grandmother. "Are you sure you're not infected yourself?"

She rolled her eyes. "Don't go all Body Snatchers on me, Carl. I know the two of you can't leave the farm right now. So if you want to let him go, I'll look after him." She shrugged and turned her head away imperiously. "I've said my piece. Now it's your decision."

Lincoln drove the truck as far as the highway, then reluctantly let his grandmother take the wheel. He loved the old machine, which still had the engine his grandfather had installed, years before Lincoln was born, to run on their home-pressed soybean oil.

"I plan to take the most direct route," his grandmother announced. "Through Macon. Assuming your friends have no objection."

Lincoln squirmed. "Don't call them that!"

"I'm sorry." She glanced at him sideways. "But I still need to know."

Reluctantly, Lincoln forced himself to picture the drive ahead, and he felt a surge of *rightness* endorsing the plan. "No problem with that," he muttered. He was under no illusion that he could prevent the Stevelets from influencing his thoughts, but deliberately consulting them, as if there were a third person sitting in the cabin, made him feel much worse.

He turned to look out the window, at the abandoned fields and silos passing by. He had been down this stretch of highway a hundred times, but each piece of blackened machinery now carried a disturbing new poignancy. The Crash had come 30 years ago, but it still wasn't truly over. The Stevelets aspired to do no harm—and supposedly they got better at that year by year—but they were still far too stupid and stubborn to be relied upon to get anything right. They had just robbed his parents of two skilled pairs of hands in the middle of the harvest; how could they imagine that that was harmless? Millions of people around the world had died in the Crash, and that couldn't all be blamed on panic and self-inflicted casualties. The government had been crazy, bombing half the farms in the Southeast; everyone agreed now that it had only made things worse. But many other deaths could not have been avoided, except by the actions of the Stevelets themselves.

You couldn't reason with them, though. You couldn't shame them, or punish them. You just had to hope they got better at noticing when they were screwing things up, while they forged ahead with their impossible task.

"See that old factory?" Lincoln's grandmother gestured at a burned-out metal frame drooping over slabs of cracked concrete, standing in a field of weeds. "There was a conclave there, almost 20 years ago."

Lincoln had been past the spot many times, and no one had ever mentioned this before. "What happened? What did they try?"

"I heard it was meant to be a time machine. Some crackpot had put his plans on the Net, and the Stevelets decided they had to check it out. About a hundred people were working there, and thousands of animals."

Lincoln shivered. "How long were they at it?"

"Three years." She added quickly, "But they've learned to rotate the workers now. It's rare for them to hang on to any individual for more than a month or two."

A month or two. A part of Lincoln recoiled, but another part thought: that wouldn't be so bad. A break from the farm, doing something different. Meeting new people, learning new skills, working with animals.

Rats, most likely.

Steve Hasluck had been part of a team of scientists developing a new kind of medical nanomachine, refining the tiny surgical instruments so they could make decisions of their own, on the spot. Steve's team had developed an efficient way of sharing computing power across a whole swarm, allowing them to run large, complex programs known as "expert systems" that codified decades of biological and clinical knowledge into pragmatic lists of rules. The nanomachines didn't really "know" anything, but they could churn through a very long list of "If A and B, there's an 80 percent chance of C" at blistering speed, and a good list gave them a good chance of cutting a lot of diseases off short.

Then Steve found out that he had cancer, and that his particular kind wasn't covered by anyone's list of rules.

He took a batch of the nanomachines and injected them into a roomful of caged rats, along with samples of his tumor. The nanomachines could swarm all over the tumor cells, monitoring their actions constantly. The polymer radio antennas they built beneath the rats' skin let them share their observations and hunches from host to host, like their own high-speed wireless Internet, and report their findings back to Steve himself. With that much information being gathered, how hard could it be to understand the problem and fix it? But Steve and his colleagues couldn't make sense of the data. Steve got sicker, and all the gigabytes pouring out of the rats remained as useless as ever.

Steve tried putting new software into the swarms. If nobody knew how to cure his disease, why not let the swarms work it out? He gave them access to vast clinical databases and told them to extract their own rules. When the cure still failed to appear, he bolted on more software, including expert systems seeded with basic knowledge of chemistry and physics. From this starting point, the swarms worked out things about cell membranes and protein folding that no one had ever realized before, but none of it helped Steve.

Steve decided that the swarms still had too narrow a view. He gave them a general-purpose knowledge acquisition engine and let them drink at will from the entire Web. To guide their browsing and their self-refinement, he gave them two clear goals. The first was to do no harm to their hosts. The second was to find a way to save his life or, failing that, to bring him back from the dead.

That last rider might not have been entirely crazy, because Steve had arranged to have his body preserved in liquid nitrogen. If that had happened, maybe the Stevelets would have spent the next 30 years ferrying memories out of his frozen brain. Unfortunately, Steve's car hit a tree at high speed just outside of Austin, TX, and his brain ended up as flambé.

This made the news, and the Stevelets were watching. Between their lessons from the Web and whatever instincts their creator had given them, they figured out that they were now likely to be incinerated themselves. That wouldn't have mattered to them if not for the fact that they'd decided the game wasn't over. There'd been nothing about resurrecting charred flesh in the online medical journals, but the Web embraced a wider range of opinions. The swarms had read the sites of various groups convinced that self-modifying software could find ways to make itself smarter, and then smarter again, until nothing was beyond its reach. Resurrecting the dead was right there on every bullet-pointed menu of miracles.

The Stevelets knew that they couldn't achieve anything as a plume of smoke wafting out of a rat crematorium, so the first thing they engineered was a breakout. From the cages, from the building, from the city. The original nanomachines couldn't replicate themselves, and could be destroyed in an instant by a simple chemical trigger, but somewhere in the sewers or the fields or the silos, they had inspected and dissected each other to the point that they were able to reproduce. They took the opportunity to alter some old traits: the new generation of Stevelets lacked the suicide switch, and they resisted external meddling with their software.

They might have vanished into the woods to build scarecrow Steves out of sticks and leaves, but their software roots gave their task rigor, of a kind. From the Net they had taken ten thousand crazy ideas about the world, and though they lacked the sense to see that they were crazy, they couldn't simply take anything on faith, either. They had to test these claims, one by one, as they groped their way toward Stevescence. And while the Web had suggested that with their power to self-modify they could achieve anything, they found that in reality there were countless crucial tasks that remained beyond their abilities. Even with the aid of dexterous mutant rats, Steveware Version 2 was never going to reëngineer the fabric of space-time, or resurrect Steve in a virtual world.

Within months of their escape, it must have become clear to them that some hurdles could be jumped only

with human assistance, because that was when they started borrowing people. Doing them no physical harm, but infesting them with the kinds of ideas and compulsions that turned them into willing recruits.

The panic, the bombings, the Crash, had followed. Lincoln hadn't witnessed the worst of it. He hadn't seen conclaves of harmless sleepwalkers burned to death by mobs, or fields of grain napalmed by the government, lest they feed and shelter nests of rats.

Over the decades, the war had become more subtle. Counterware could keep the Stevelets at bay, for a while. The experts kept trying to subvert the Steveware, spreading modified Stevelets packed with propositions that aimed to cripple the swarms or, more ambitiously, make them believe that their job was done. In response, the Steveware had developed verification and encryption schemes that made it ever harder to corrupt or mislead. Some people still advocated cloning Steve from surviving pathology samples, but most experts doubted that the Steveware would be satisfied with that, or taken in by any misinformation that made the clone look like something more.

The Stevelets aspired to the impossible and would accept no substitutes, while humanity longed to be left unmolested, to get on with more useful tasks. Lincoln had known no other world, but until now he'd viewed the struggle from the sidelines, save shooting the odd rat and queuing up for his counterware shots.

So what was his role now? Traitor? Double agent? Prisoner of war? People talked about sleepwalkers and zombies, but in truth there was still no right word for what he had become.

Late in the afternoon, as they approached Atlanta, Lincoln felt his sense of the city's geography warping, the significance of familiar landmarks shifting. *New information coming through.* He ran one hand over each of his forearms, where he'd heard the antennas often grew, but the polymer was probably too soft to feel beneath the skin. His parents could have wrapped his body in foil to mess with reception, and put him in a tent full of bottled air to keep out any of the chemical signals that the Stevelets also used, but none of that would have rid him of the basic urge.

As they passed the airport, then the tangle of overpasses where the highway from Macon merged with the one from Alabama, Lincoln couldn't stop thinking about the baseball stadium up ahead. Had the Stevelets commandeered the home of the Braves? That would have made the news, surely, and ramped the war up a notch or two.

"Next exit," he said. He gave directions that were half his own, half flowing from an eerie dream logic, until they turned a corner and the place where he knew he had to be came into view. It wasn't the stadium itself; that had merely been the closest landmark in his head, a beacon the Stevelets had used to help guide him. "They booked a whole motel!" his grandmother exclaimed.

"Bought," Lincoln guessed, judging from the amount of visible construction work. The Steveware controlled vast financial assets, some flat-out stolen from sleepwalkers but much of it honestly acquired by trading the products of the rat factories: everything from high-grade pharmaceuticals to immaculately faked designer shoes.

The original parking lot was full, but there were signs showing the way to an overflow area near what had once been the pool. As they headed for reception, Lincoln's thoughts drifted weirdly to the time they'd come to Atlanta for one of Sam's spelling competitions.

There were three uniformed government Stevologists in the lobby, seated at a small table with some equipment. Lincoln went first to the reception desk, where a smiling young woman handed him two room keys before he'd had a chance to say a word. "Enjoy the conclave," she said. He didn't know if she was a zombie like him or a former motel employee who'd been kept on, but she didn't need to ask him anything.

The government people took longer to deal with. His grandmother sighed as they worked their way through a questionnaire, and then a woman called Dana took Lincoln's blood. "They usually try to hide," Dana said, "but sometimes your counterware can bring us useful fragments, even when it can't stop the infection."

As they ate their evening meal in the motel dining room, Lincoln tried to meet the eyes of the people around him. Some looked away nervously; others offered him encouraging smiles. He didn't feel as if he was being inducted into a cult, and it wasn't just the lack of pamphlets or speeches. He hadn't been brainwashed into worshipping Steve; his opinion of the dead man was entirely unchanged. Like the desire to reach Atlanta in the first place, his task here would be far more focused and specific. To the Steveware he was a kind of machine, a machine it could instruct and tinker with the way Lincoln could control and customize his phone, but the Steveware no more expected him to share its final goal than he expected his own machines to enjoy his music, or respect his friends.

Lincoln knew that he dreamed that night, but when he woke he had trouble remembering the dream. He

knocked on his grandmother's door; she'd been up for hours. "I can't sleep in this place," she complained. "It's quieter than the farm."

She was right, Lincoln realized. They were close to the highway, but traffic noise, music, sirens, all the usual city sounds, barely reached them.

They went down to breakfast. When they'd eaten, Lincoln was at a loss to know what to do. He went to the reception desk; the same woman was there.

He didn't need to speak. She said, "They're not quite ready for you, sir. Feel free to watch TV, take a walk, use the gym. You'll know when you're needed."

He turned to his grandmother. "Let's take a walk."

They left the motel and walked around the stadium, then headed east away from the highway, ending up in a leafy park a few blocks away. All the people around them were doing ordinary things: pushing their kids on swings, playing with their dogs. Lincoln's grandmother said, "If you want to change your mind, we can always go home."

As if his mind were his own to change. Still, at this moment the compulsion that had brought him here seemed to have waned. He didn't know whether the Steveware had taken its eyes off him or was deliberately offering him a choice, a chance to back out.

He said, "I'll stay." He dreaded the idea of hitting the road only to find himself summoned back. Part of him was curious, too. He wanted to be brave enough to step inside the jaws of this whale, on the promise that he would be disgorged in the end.

They returned to the motel, ate lunch, watched TV, ate dinner. Lincoln checked his phone; his friends had been calling, wondering why he hadn't been in touch. He hadn't told anyone where he'd gone. He'd left it to his parents to explain everything to Sam.

He dreamed again, and woke clutching at fragments. Good times, an edge of danger, wide blue skies, the company of friends. It seemed more like a dream he could have had on his own than anything that might have come from the Steveware cramming his mind with equations so he could help test another crackpot idea that the swarms had collected 30 years ago by Googling the physics of immortality.

Three more days passed, just as aimlessly. Lincoln began to wonder if he'd failed some test, or if there'd been a miscalculation leading to a glut of zombies.

Early in the morning of their fifth day in Atlanta, as Lincoln splashed water on his face in the bathroom, he felt the change. Shards of his recurrent dream glistened potently in the back of his mind, while a set of directions through the motel complex gelled in the foreground. He was being summoned. It was all he could do to bang on his grandmother's door and shout out a garbled explanation before he set off down the corridor.

She caught up with him. "Are you sleepwalking? Lincoln?"

"I'm still here, but they're taking me soon."

She looked frightened. He grasped her hand and squeezed it. "Don't worry," he said. He'd always imagined that when the time came he'd be the one who was afraid, drawing his courage from her.

He turned a corner and saw the corridor leading into a large space that might once have been a room for conferences or weddings. Half a dozen people were standing around; Lincoln could tell that the three teenagers were fellow zombies, while the adults were just there to look out for them. The room had no furniture but contained an odd collection of items, including four ladders and four bicycles. There was cladding on the walls, *soundproofing*, as if the whole building weren't quiet enough already.

Out of the corner of his eye, Lincoln saw a dark mass of quivering fur: a swarm of rats, huddled against the wall. For a moment his skin crawled, but then a heady sense of exhilaration swept his revulsion away. His own body held only the tiniest fragment of the Steveware; at last he could confront the thing itself.

He turned toward the rats and spread his arms. "You called, and I came running. So what is it you want?" Disquietingly, memories of the Pied Piper story drifted into his head. Irresistible music lured the rats away. Then it lured away the children.

The rats gave no answer, but the room vanished.

Ty hit a patch of dust on the edge of the road, and it rose up around him. He whooped with joy and pedaled twice as hard, streaking ahead to leave his friends immersed in the cloud.

Errol caught up with him and reached across to punch him on the arm, as if he'd raised the dust on purpose. It was a light blow, not enough to be worth retribution; Ty just grinned at him.

It was a school day, but they'd all sneaked off together before lessons began. They couldn't do anything in town—there were too many people who'd know them—but then Dan had suggested heading for the water tower. His father had some spray paint in the shed. They'd climb the tower and tag it.

There was a barbed-wire fence around the base of the tower, but Dan had already been out here on the weekend and started a tunnel, which didn't take them long to complete. When they were through, Ty looked up and felt his head swimming. Carlos said, "We should have brought a rope."

"We'll be okay."

Chris said, "I'll go first."

"Why?" Dan demanded.

Chris took his fancy new phone from his pocket and waved it at them. "Best camera angle. I don't want to be looking up your ass."

Carlos said, "Just promise you won't put it on the Web. If my parents see this, I'm screwed."

Chris laughed. "Mine, too. I'm not that stupid."

"Yeah, well, you won't be on camera if you're holding the thing."

Chris started up the ladder. Dan went next, with one paint can in the back pocket of his jeans. Ty followed, then Errol and Carlos.

The air had been still down on the ground, but as they went higher a breeze came out of nowhere, cooling the sweat on Ty's back. The ladder started shuddering; he could see where it was bolted securely to the concrete of the tower, but in between it could still flex alarmingly. He'd treat it like a fairground ride, he decided: a little scary, but probably safe.

When Chris reached the top, Dan let go of the ladder with one hand, took the paint can, and reached out sideways into the expanse of white concrete. He quickly shaped a blue background, a distorted diamond, and then called down to Errol, who was carrying the red.

When Ty had passed the can up, he looked away, out across the expanse of brown dust. He could see the town in the distance. He glanced up and saw Chris leaning forward, gripping the ladder with one hand behind his back while he aimed the phone down at them.

Ty shouted up at him, "Hey, Scorsese! Make me famous!"

Dan spent five minutes adding finicky details in silver. Ty didn't mind; it was good just being here. He didn't need to mark the tower himself; whenever he saw Dan's tag, he'd remember this feeling.

They clambered down, then sat at the base of the tower and passed the phone around, checking out Chris's movie.

Lincoln had three rest days before he was called again, this time for four days in succession. He fought hard to remember all the scenes he was sleepwalking through, but even with his grandmother adding her accounts of the "playacting" she'd witnessed, he found it hard to hold on to the details.

Sometimes he hung out with the other actors, shooting pool in the motel's game room, but there seemed to be an unspoken taboo against discussing their roles. Lincoln doubted that the Steveware would punish them even if they managed to overcome the restraint, but it was clear that it didn't want them to piece too much together. It had even gone to the trouble of changing Steve's name (as Lincoln and the other actors heard it, though presumably not Steve himself), as if the anger they felt toward the man in their ordinary lives might have penetrated into their roles. Lincoln couldn't even remember his own mother's face when he was Ty; the farm, the Crash, the whole history of the last 30 years, was gone from his thoughts entirely.

In any case, he had no wish to spoil the charade. Whatever the Steveware thought it was doing, Lincoln hoped it would believe it was working perfectly, all the way from Steve's small-town childhood to whatever age it needed to reach before it could write this creation into flesh and blood, congratulate itself on a job well done, and then finally, mercifully, dissolve into rat piss and let the world move on.

Without warning, a fortnight after they'd arrived, Lincoln was no longer needed. He knew it when he woke, and after breakfast the woman at reception asked him, politely, to pack his bags and hand back the keys. Lincoln didn't understand, but maybe Ty's family had moved out of Steve's hometown, and the friends hadn't stayed in touch. Lincoln had played his part; now he was free.

When they returned to the lobby with their suitcases, Dana spotted them and asked Lincoln if he was willing to be debriefed. He turned to his grandmother. "Are you worried about the traffic?" He'd already phoned his father and told him they'd be back by dinnertime.

She said, "You should do this. I'll wait in the truck."

They sat at a table in the lobby. Dana asked his permission to record his words, and he told her everything he could remember.

When Lincoln had finished, he said, "You're the Stevologist. You think they'll get there in the end?"

Dana gestured at her phone to stop recording. "One estimate," she said, "is that the Stevelets now comprise a hundred thousand times the computational resources of all the brains of all the human beings who've ever lived."

Lincoln laughed. "And they still need stage props and extras, to do a little VR?"

"They've studied the anatomy of ten million human brains, but I think they know that they still don't fully understand consciousness. They bring in real people for the bit parts, so they can concentrate on the star. If you gave them a particular human brain, I'm sure they could faithfully copy it into software, but anything more complicated starts to get murky. How do they know their Steve is conscious, when they're not conscious themselves? He never gave them a reverse Turing test, a checklist they could apply. All they have is the judgment of people like you."

Lincoln felt a surge of hope. "He seemed real enough to me." His memories were blurred—and he wasn't even absolutely certain which of Ty's four friends was Steve—but none of them had struck him as less than human.

Dana said, "They have his genome. They have movies, they have blogs, they have e-mails: from Steve and a lot of people who knew him. They have a thousand fragments of his life. Like the borders of a giant jigsaw puzzle."

"So that's good, right? A lot of data is good?"

Dana hesitated. "The scenes you described have been played out thousands of times before. They're trying to tweak their Steve to write the right e-mails, pull the right faces for the camera—by himself, without following a script like the extras. A lot of data sets the bar very high."

As Lincoln walked out to the parking lot, he thought about the laughing, carefree boy he'd called Chris. Living for a few days, writing an e-mail—then memory-wiped, re-set, started again. Climbing a water tower, making a movie of his friends, but later turning the camera on himself, saying one wrong word—and wiped again.

A thousand times. A million times. The Steveware was infinitely patient, and infinitely stupid. Each time it failed, it would change the actors, shuffle a few variables, and run the experiment over again. The possibilities were endless, but it would keep on trying until the sun burned out.

Lincoln was tired. He climbed into the truck beside his grandmother, and they headed for home. TR

Greg Egan's science fiction has received the Hugo Award and the John W. Campbell Memorial Award.

Fiction

The Interoperation

Architecture had given way to software management. So he turned buildings into construction programs.

By Bruce Sterling

Yuri pulled his sons from school to watch the big robot wreck the motel. His wife had packed a tasty picnic lunch, but 11-year-old Tommy was a hard kid to please. ¶ "You said a giant robot would blow that place up," Tommy said. ¶ "No, son, I told you a robot would 'take it down,'" said Yuri. "Go shoot some pictures for your mom." ¶ Tommy swung his little camera, hopped his bamboo bike, and took off. ¶ Yuri patiently pushed his younger son's smaller bike across the sunlit tarmac. Nick, age seven, was learning to ride. His mother had dressed him for the ordeal, so Nick's head, knees, feet, fists, and elbows were all lavishly padded with brightly colored foam. Nick had the lumpy plastic look of a Japanese action figure.

Under the crystalline spring sky, the robot towered over the Costa Vista Motel like the piston-legged skeleton of a monster printer. The urban recycler had already briskly stripped off the motel's roof. Using a dainty attachment, it remorselessly nibbled up bricks.

The Costa Vista Motel was the first, last, and only building that Yuri Lozano had created as a certified, practicing architect. It had been "designed for disassembly," way back in 2020. So today, some 26 years later, Yuri had hired the giant deconstruction-bot to fully reclaim the motel's materials: the bricks, the solar shingles, the electrical fixtures, the metal plumbing. The structure was being defabricated, with a mindless precision, right down to its last, least, humble hinges.

As he patiently guided the wobbling Nick across the motel's weedy, deserted parking lot, Yuri's reaction to the day was deep relief. He had never liked the Costa Vista. Never—not since it had left his design screen.

Once it had looked so good: poised there, safe within the screen. He'd been so pleased with the plan's spatial purity, the way the 3-D volumes massed together, the nifty way the structure fit the site … . But the motel's contractors had been a bunch of screwups. Worse yet, the owners were greedy morons.

So Yuri had been forced to stand by while his digital master plans were cruelly botched at the hands of harsh reality. Cheap, flimsy materials. Bottom-of-the-barrel landscaping. Tacky signage. Lame interior décor. Even the name "Costa Vista" was a goofy choice for a motel off an interstate in Michigan.

Yuri had derived one major benefit from this painful experience. He had stopped calling himself an "architect." After his humiliation at the Costa Vista, he'd packed up his creative ego and thrown in his lot with the inevitable.

He had joined the comprehensive revolution attacking every aspect of the construction-architecture-engineering business. The "Next Web." The "Geo-Web." "Ubiquity." The "Internet of Things." It had a hundred names because it had a thousand victims, for the old-school Internet had busted loose to invade the world of atoms. Not just certain aspects of harsh reality—the works.

The architect's blueprints were just the first frontier to fall to comprehensive software management. The structural engineering would go, too. Then construction: the trades, the suppliers … . Then the real-estate biz, the plumbing and electrical, the energy flows, the relationships to the city's grids and the financing sector, the ever-growing thicket of 21st-century sustainabil-

ity regulation: yes, all of it would digitize. Everything. "Total building life-cycle management." People didn't wire houses anymore—they "sheltered the network."

Nowadays, in the stolid and practical 2040s, Yuri called himself the "sysadmin-CEO" of the "Lozano Building Network." Yuri's enterprise was thriving; he had more work than he and his people could handle. He had placed himself in the thick of the big time. Whenever he carved out one day off to spend with his two sons, a sprawling network sensed his absence and shivered all over.

The Lozano Building Network was ripping up dead midwestern suburbs and heaving up sustainable digital buildings by the hundreds. That was the work of the modern world.

Yuri knew that system: its colossal strength, and its hosts of cracks, shortfalls, and weaknesses.

Yuri also knew that his company's contract buildings were crap.

Ninety percent of all buildings were always crap. That was because 90 percent of all people had no taste. Yuri understood that; he was almost at peace with that. But it still burned him, it ached and it stung, that he had never built a thing that deserved to last.

The Lozano Building Network didn't create fine buildings. It instantiated shelter goods. The mass of workaday, crowd-pleasing real-estate fakery that arose from his network wasn't "architecture." It was best described as "hard copy."

To watch this building disassembled in this sweet spring morning reminded him that his life hadn't always been this way. In his own sweet spring, Yuri had dreamed of creating classics. He'd dreamed of structures that would tower on the planet's surface like brazen, gleaming symbols of excellence.

Yuri had never built any such place. He was coming to realize, with a sinister middle-aged pang, that he never would.

Watching the Costa Vista Motel disappear without a trace—no, he couldn't call himself unhappy about that. He felt eased and liberated. Denied the glory, he could at least erase the shame.

Tommy, always a bundle of energy, had pedaled all around the doomed motel. Somewhere, the kid had ditched his safety helmet. "Look, Dad, why don't you just blow it up? The way that big dumb robot picks at it, this'll take us all day!"

"We've got all day," Yuri told him serenely. "Tonight we bring jackhammers."

Tommy brushed hair from his eager eyes. "Jackhammers, Dad? Can I touch the big jackhammers?"

"Maybe, son. If you don't tell your mom."

Nick yelped, jealous for attention. "Come on, Dad! Push the bike, push it, Dad!" Nick was the frailer and smarter of the two boys. His mother doted on him.

Yuri hitched his pants and shoved Nick's bike. The kid almost had the hang of it. Yuri secretly let him go.

Nick rolled off beautifully, his padded feet eager on his pedals. Then instability set in. Nick teetered into a wobbly, desperate struggle. Finally he crashed.

Tommy circled his fallen brother, derisively ringing his bike bell. "Get up, wimp, loser!"

Yuri bent and disentangled Nick from the candy-colored frame. "Fail early, fail often, Nick. You're not hurt."

"I'm not hurt," Nick agreed mournfully.

"A ride in a parking lot is just prototyping. Get back in your saddle."

Nick balked, and looked searchingly into Yuri's face. "Are you sad, Dad? You look sad."

"I'm not sad, son."

"I'll never learn how to ride a bike. Will I?"

"Yes, son, you will! You will master this bicycle! A bicycle is the world's most efficient means of transportation! And this bicycle will give you—Nicholas Lozano—a vastly increased power to navigate urban space!"

Nick was properly impressed. He climbed back on his bike.

"Nick, you are learning this much faster than your brother did. Don't tell Tommy I said that."

"Yeah, sure, Dad! Okay! Push me now!"

Tommy zoomed back and skidded to a sudden halt, his freckled face pale. He slung his arm out. "Dad, Mom is coming! And she brought Aunt Carmen!"

Yuri glanced across the lot. Tommy's dire news was true.

Tommy was panting. "Are we in big trouble, Dad?"

"You'd better let me handle this."

Yuri's wife and sister-in-law floated toward him on twin Segways. Like their famous father, the Roebel sisters were obsessed with Segways. After 45 years of niche applications, the ingenious machines had achieved a certain period charm, like monorails and the Graf Zeppelin.

It was unlike Gretchen to show up when he was taking some quality time with the boys. On the contrary: when the kids were out from underfoot, Gretchen indulged herself by taking scented bubble baths and surfing upscale websites.

And Carmen was here with her, all the way from San Francisco. Carmen, arriving with no warning? Carmen? Nobody had ever been able to do a thing with Carmen.

The Segway smoothly bobbed into place, and his wife's narrow face was the picture of woe. "Oh, honey, it's just the worst."

"Somebody's died?"

"No, no," Carmen wailed. "My dad got a big new commission!"

The people who were nearest to François Roebel were a frantically unhappy lot. For Roebel was a grand master of computer-aided architecture.

Roebel was a major world architect who had forced digital design to speak its own aesthetic language—comprehensive, authentic, symphonic. His signature buildings were like nothing previously seen on planet Earth. They made the work of Gehry and Calatrava look like dress rehearsals.

Roebel himself was a squinty, boozy, bewhiskered little geek. He had an ego the size of the rock of Gibraltar and was given to splashy overspending, frantic womanizing, major fits of temper, and impromptu trips to Indonesia.

Certain people imagined that he, Yuri Lozano, had married Gretchen Roebel in order to get closer to her famous architect father. The truth was entirely the opposite: he'd married Gretchen in order to take her far away from Roebel. Snatching Gretchen from her dysfunctional family was like hauling a young woman from a burning car.

Yuri had no regrets about his bold intervention. Gretchen loved him, and besides, the scary example of Carmen had fully validated his choice. Carmen had never escaped from the black-hole orbit of Roebel, who'd always been the center of his own private universe. So poor Carmen had ended up exactly like her late mom: a doomy, subservient, hand-flapping mystic with a brain like scattered granola.

For François Roebel, architectural design space was a dark and terrible domain. It was a harsh arena of combative nightmare, a realm of endlessly ramifying pull-ins, pop-outs, twists, deformations, mirrored ramps, and cryptic passages. Ever the hero within his own mind, Roebel relentlessly pushed design software past all sane limits, feverishly conjuring structures, then bullying them into raw physical existence in a welter of lawsuits and scandals.

Roebel had lived for decades on the virtual-actual edge, where the unprecedented phantoms roiling in his screen became awesome urban showcases fit to stun and amaze passers-by. Given their wild-eyed engineering, they might also spindle and mutilate their inhabitants, but the risks of his art to others never concerned the great man.

For Roebel, anyone willing to settle for less than the insanely great was a traitor to be pitilessly scourged. Roebel made enemies the way lesser men made popcorn.

Yuri took a train to San Francisco to pay court to the grand master. It took him two days to arrive on Roebel's doorstep.

Roebel, as was his habit, was all ticked off about that.

"Where the hell is Carmen?" Roebel screeched. "I haven't had a decent meal in five days! Carmen's trying to starve me!"

The ancient visionary, always scrawny, looked downright spidery by now—he'd lost so much flesh that he'd been reduced to vector graphics.

"Oh, the nephews always love a visit from their favorite aunt," Yuri lied gallantly.

"I am the very last global starchitect! I am the last instantiation of a dying breed!" rasped Roebel. "And you couldn't fly over here?"

"I needed some time on the train to clear my construction agenda," Yuri soothed. Yuri always agreed to "help" Roebel with his projects. There was very little risk in this. Sooner or later, Roebel's clients always realized that Roebel had become impossible.

The genius could be humored, but only when his burning obsessions were channeled into some narrow, immediate path.

So Yuri loudly dragged a clanging metal chair over the naked cement of Roebel's dusty garage studio. He set himself before the architect's legendary personal workstation, jacked up a knee, and bridged his fingers over it. "So, François, here I am at last. Just show me what you've got. Let's see all the concept sketches!"

Roebel tottered over, rolled up his blue linen sleeves over his stick-thin, liver-spotted forearms, and reached reluctantly through a clutter of empty sport-drink cans. He fished out a cheap toy peripheral. It was a skull-wrapping plastic headset, badly faded with age. "I'm sure you've never seen one of these."

"Tell me all about that."

Roebel drew himself up regally. "I'm sketching in ClearWorks with this cortico-cognitive headset!"

Yuri cleared his throat. "You're designing in ClearWorks? With some kind of brain-reader gizmo?"

"ClearWorks is the finest design program ever crafted!"

"François, ClearWorks is 30 years old." Roebel would be better off with pencils and a set of children's blocks.

"Well, what the hell are you here for?" Roebel barked. "I need you to make ClearWorks interoperate with that foul malarkey that your nest of thieves

calls software!" Roebel was breathing heavily. "Those so-called 'tools' you use—you can't drill one hole in a girder without 40 interlocking safety forms!"

"If you're having trouble with your system, I'd be glad to have a look." Yuri popped the chromed clips on his moroccan-leather shoulder bag. "I brought some top-end diagnostics in the laptop."

"Put that stupid toy away, I know you're a software monkey!" snarled Roebel. "ClearWorks is architecture! Because it's software architecture by an information architect!"

"I haven't seen ClearWorks since I left college," said Yuri. "Does ClearWorks interoperate with current legal codes?"

"I need your lawyers like I need a hole in the head!"

His question answered, Yuri offered a sunny smile. "I always loved that kind of boldness, François! Fire up your program—let's have a good long look!"

With his bluff called, Roebel reluctantly pressed the lozenge-shaped metal Start button on his towering desktop engine. Roebel still used a specialty CAD workstation. The discolored machine, its shell scrubbed with acetone and its keyboard worn to nubs, had a militant, strutting, look-at-me-being-all-cyber aesthetic. Roebel's workstation looked fit to redesign the whole Milky Way, though, truth be told, it had about 10 percent of the processing capacity of a modern kid's throwaway wristwatch.

"User lock-ins and proprietary formats," Roebel muttered, his throaty old-man's voice matching the ancient growl of his workstation's stricken hard disk. "Those punk-ass chumps in the channels of distribution, they won't even show you the end-user license agreements."

The archaic vacuum tube flickered as the workstation struggled to boot. "And what on earth happened to the people?" Roebel griped, avoiding Yuri's eyes. "The banks, the unions, the professions, every level of government … all of 'em melted down into one giant ball of software mud! No more creative giants … they're all nickel-and-dime windup monkeys in a crazy world that gets more interactive every day!"

"Tell me about your client," said Yuri, angling for a change of subject.

Roebel gave a sly yellow grin. "The Church of Symbiosis."

"They're commissioning another temple from you? That's terrific news," said Yuri. His heart sank.

The Church of Symbiosis … could it get any worse than this? François Roebel was the picture of sanity compared with his favorite clients.

The Church of Computer-Human Symbiosis was an aging group of California hacker cranks who had inherited the vast fortune of a vanished social-software company. They had long been Roebel's ideal patrons, for they were crazily rich, all-forgiving, and incapable of judgment.

Over the decades, Roebel had built the cult an awesome set of monumental churches. His temples were top-end architecture glamour hits; glossy photo books about them weighed down coffee tables on six continents.

Nobody ever worshiped in the amazing churches Roebel had built, because the cult was too crazy and scary. Furthermore, the roofs leaked and all the utilities malfunctioned. Still, that didn't much matter to the cultists. They were serenely indifferent to such earthly concerns, since they spent most of their waking lives playing immersive simulation games.

Roebel tinkered aimlessly with his keyboard. The glassy screen was blank.

"It'll launch any minute," he lied. "The system's been a little temperamental."

Pity gnawed at Yuri. Pity was a dangerous sentiment in the company of the grand master, but Yuri couldn't help it. Year by year, Roebel had lost so much. His fancy downtown office, his staffers, his financial contacts, his engineers and subcontractors. Roebel still worked—when he worked at all—on this ancient CAD system designed for building French fighter aircraft.

The screen flickered. "There it goes," he crowed, as if the machine's effort had achieved something. "I'll just have to strap on the skull set. Later."

Whatever had happened to the old man? Normally he'd shed a violent storm of wild schemes and concepts, each one less practically achievable than the last.

Yuri wasn't sure if this grim void meant disaster or deliverance for him. In either case, he felt sincere dismay.

"François, I have a very positive feeling about your new commission. We'll have a job of work with the interoperation issues, but at least we've got a client sympathetic to your aims."

Roebel squinted. "You're not fooling me any, you know."

"I beg your pardon?"

Roebel tossed his peripheral aside and abandoned his keyboard. "Just knock all that off, that crap when you sweet-talk me! You sound like a real-estate agent! You ran off with my daughter—and that's the last thing you did that took any guts! You never soar, boy! You're like a pig in mud!"

"Let's take that discussion offline," Yuri said. "Let's call Gretchen right now, and the grandsons, back in Michigan. They'll be wondering how things are going here. You never call us, you know."

"A 12-year-old and an eight-year-old."

"The boys are 11 and seven."

"I was thinking ahead. Do I look like I want to wet-nurse your kids? I just received a major commission! 'Back to Michigan'—to hell with your Michigan. That whole place is nothing but forest! You can hear the crickets chirping in Flint, Saginaw, and Grand Rapids! Your kids are like two sandlot baseball kids straight outta Norman Rockwell! And Gretchen … Gretchen doesn't even show up here! Where the hell is she—still putting her spice racks in order?"

"Gretchen looks after the network in my absence. She's got a talent for billing and accounting."

"That's not a 'talent,' you dolt! I know you understand what's really at stake here! I taught you architecture when you were some cornshuck kid from Kentucky wandering into my office like a lost soul! And speaking of lost souls—where the hell is Preston? I told Preston to be here with us half an hour ago!"

Preston Mengies was an architecture critic who had once been the PR man in Roebel's San Francisco office. He had earnestly pumped up Roebel's worldwide reputation, until his doomed relationship with the hopelessly unstable Carmen Roebel made that effort impossible.

Despite everything Preston had suffered at the old man's hands, he arrived. He'd bicycled in from South of Market and thoughtfully brought some Chinese food.

Yuri sorrowed at the sight of him. Preston Mengies had once been a very sharp and fluent guy—a sarcastic little weirdo, to tell the truth, but fun to hang around with.

As a result of his long entanglement with Roebel, though, he had become a threadbare, gaunt, myopic, beaten character.

Nowadays, Preston spent his lonely hours grooming architecture websites. There he gamely removed the moronic popular commentary and tried to drum up some intelligent interest in the doctrines of Arts & Crafts, Futurism, the modern movement, the postmodern movement, and New Urbanism.

These were architectural schemes that long-forgotten people had created with pencils on paper. No proper 21st-century person could tell these primitive notions apart. Still, some critic was bound to take a keen interest in such efflorescences of human genius, and it was bound to be some weedy obsessive like Preston Mengies.

Roebel sipped and scowled at the hot-and-sour soup, but he had clearly lost the thread of the action. All the old man could do was bitterly rant about "lawyers" and "hoodwinking" and "bank fraud." The client's demands had caught him flat-footed. When he tottered off for his customary afternoon nap, it was a relief for all concerned.

He left Yuri and Preston to patch something together for the client's imminent visit.

"How are the kids?" ventured Preston, who had never had any kids.

"The boys are both great, thanks."

"They're normal kids?" said Preston, his eyes flickering sideways.

"Oh, yeah, they're completely normal boys," said Yuri. "Not at all like the maestro there; they just faded right back into the universal gene pool."

Preston brightened at this sally; he was a critic, so a little acerbic sarcasm always cheered him up. He munched his cold shrimp chow mein and gestured at the workstation with his cheap plastic chopsticks. "Did he ask you to touch that dinosaur? I sure wouldn't touch that wreck if I were you."

"Why is that, Preston?"

"You know how he's trying to patch that fossil to modern standards—and to get his own way, right in the teeth of the entire construction industry? Well, he finally blew it. He had a massive, comprehensive data loss. No upgrade path forward. And no way back. He's completely stuck now. He's neck deep in the mud of defunct code."

Yuri munched a heat-blistered egg roll stuffed with gleaming California tofu. "He claimed he was designing on ClearWorks. I just couldn't believe that."

"Nobody runs ClearWorks," scoffed Preston. "That's the greatest design platform ever created, but no modern professional could use it. It doesn't interoperate with other disciplines."

"It's even worse than that," Yuri admitted. "Out in the Midwest, we do interoperate, so we became all the other disciplines. As soon as I gave up on 'architecture' and admitted that I was administering software, well … step by step, I took over the site, the structure, the skin of the building, all the services. We supply the space plans; we even retail the furnishings. But we're never architects. Not at all. We're real estate, interior design, engineering, landscaping, plumbing, electrical … we're the Net."

Yuri knotted his hands. "And it's all bucket-of-mud piece-of-junk legacy code! Every bit of it! Those pro-

grams all hate each other's guts! I spend 90 percent of my working time as a software clerk!"

"So basically, you never design and you never create. You just interoperate."

Yuri considered this grim assessment. "Well, yeah, that's pretty well put."

Preston warmed to his theme. "But you have to do that. Because there's a shearing force in all those different layers of software. It's a thing of eddies, and whirlpools, and brief bursts of financial energy. And the craft of architecture sold its soul so that it could survive there."

Yuri set aside a stenciled carton of moo goo gai pan. "Can I ask you something? At the Milwaukee Design Regulation Board, I've got this big keynote speech coming up …"

"How long a speech?"

"Full hour. Big dinner speech. Man, I hate those."

"How big a crowd?"

"I dunno—seven, eight hundred. Typical industry drones."

"Could you give me a grand to write that for you?"

Yuri blinked a little. "Yeah, sure, okay."

That money was peanuts, but it was clearly more cash than Preston had seen in a while, for he sat up in his steel-framed chair and seemed to regain his appetite. "Well, there's one consolation in all this. Roebel's never gonna do another building."

Yuri laughed. "Oh, sure, people keep saying that, but he keeps surprising 'em. That mean old man is gonna bury us all! He's gonna live to be 90 years old!"

"Roebel *is* 90 years old."

Yuri did some swift mental arithmetic. "Darn—where does the time go?"

Preston snagged an empty can from the desktop. "This is all he eats now—these vitamin drinks. Carmen dragged him into a couple of clinics last year. They took one look at him and they washed their hands. I don't know how he stays on his feet. He persists out of sheer spite."

Yuri considered this bleak diagnosis. Yes, François was especially gaunt and erratic, even for François. There had been one little flash where he was like his keen old self, but … no concept sketches? François Roebel was 110 percent concept sketches. "Maybe the lamp finally went out."

"Yeah, 'the well ran dry.' That's what Carmen says. You add that to his big software crash, and …" Preston flapped his hands. "It's Game Over for Pac-Man."

"Carmen came to visit us. Carmen seems pretty distraught about all this."

Carmen Roebel was always distraught—Carmen was the Queen of Distraughtness—but Preston took that news hard. It had him all itchy and gritting his teeth. The poor guy still carried a big torch for Carmen. That was a pitiful thing to see.

"She's up to her ears in debt," said Preston. "Did she tell you that?"

In point of fact, Carmen had swiftly hit Yuri up for a personal loan. Every member of the extended Roebel family hit Yuri up for loans. He'd come to consider that a basic cost of his business, something like a corporate gift to a Little League team.

Yuri sighed. "I don't suppose that François would write his will and put his affairs in good order."

"François wouldn't leave Carmen a dime! If he had a dime, he'd endow the François Roebel Perpetual Commemoration Fund." Preston shook his head. "After all these years, it's come to the crunch! Those church lunatics will show up here soon … they want to see his proposal. He's gonna fire up that relic there, and he'll show them a screen full of snow."

An empty silence stretched in Roebel's spider hole of an office, and somewhere a seagull screeched.

Yuri was no longer an architect—in point of fact, he'd probably never really been one—but he'd spent his whole adult life glossing over the bitter contradictions between complicated systems of software.

There just had to be a hack somewhere for a dire situation like this one.

"Preston, I know that this isn't quite honest, but—suppose you show 'em something out of the old man's archives? He must have dozens of unbuilt proposals. Surely those clowns can't tell the difference anyway."

"The old man sold those clowns his archives. He sold them all his files three years ago. The church paid top dollar for them, too. They've got 'em all stored down a zinc-lined bomb shelter someplace."

How, where, and why did computers let crazy geeks make so much money? Yuri wondered. Had the world ever been better off for that? Seeding the world with computers was like sprinkling it with the fairy dust of pure madness.

Preston had the shameless look of a guy doing something very stupid for the woman he loved. "Listen, Yuri: for you this story must seem pretty simple. The old man loses this commission—so what? You're doing great out there in the Rust Belt. Because you're in deconstruction; you could spend the rest of your life just tearing down the Motor City. But Carmen needs that retainer fee. She's at her wits' end."

Poor old Preston. If only he'd found the courage to abandon his idealistic dreams and take some practi-

cal action! Just tell the old man off, clonk the girl on the head, throw her into the trunk of a car, and drive off across a state line!

But it took a certain hillbilly lack of savoir faire to do something so blunt, immediate, helpful, and misogynistic. That basic course of action had worked out fine for Yuri, but Preston possessed a gentler and more refined sensibility.

The cuffs of Preston's pants were badly frayed. This tiny detail was somehow Yuri's tipping point.

"Okay," he said, straightening, "I tell you what we're gonna do here. I'm gonna fire up ClearWorks and put the program through its paces. When that old man comes back here from his nap, I'll get him jumpstarted on something."

Preston scratched his bald spot. "You really think you can do that?"

"Yeah. I know I can do it. Because I was his star student once. It's pretty simple with François. You just do something that's very clear and simple and obvious. Then he gets all excited and he bawls you out. He can't help taking over the work and redoing it all himself. So: if this piece of junk runs at all, well, the two of us will cook up some concept plan. It doesn't have to be the Taj Mahal for him to show it to his favorite client."

Preston had no better scheme to offer. He left Yuri in peace with the machine.

Yuri woke the workstation and settled in.

When he first saw the ClearWorks interface, he felt a shock of profound nostalgia. Yeah, it really was ClearWorks running there! No kidding!

ClearWorks was a simple white pane with a pair of tiny, almost invisible icons in the upper right corner. ClearWorks was so entirely clear that it looked starkly absurd. Compared to Yuri's working interfaces for the modern construction business, ClearWorks was alien.

Where was the riffling host of toolbars, templates, menus, dynamic panels, auto-updaters, dialog panels, widgets, dashboards, collision detectors, and tags? Where was the bustling cloud of counters, winkers, beepers, and blinkers?

ClearWorks was a void. A glassy, glossy innocence. ClearWorks was as pearly-white and blank as the inside of a skull.

The program's mouse, or rather its airborne bat, sat atop Roebel's workstation. When Yuri's fingertips gripped the familiar ridges of the wand, the look and feel of the program came back to him as if college were yesterday.

Space and form. Yuri was peeling through space and form. Through the torque in that bat he could actually feel space—the massiness of space, the shapeliness of space. The orderliness and rightness of planned spatiality. Geometry sliced through the white panes of simulation like a white ceramic knife through pure white cheese.

ClearWorks did just one thing well: it did form. ClearWorks did nothing but form. ClearWorks was a world in which there was only form.

Yuri recalled that ClearWorks had been programmed by just one guy. It was the brainwork of a single geek, some embittered dissident from the early CAD business. The name of this lonesome genius was Greg Something, or Bob Something, or Jim Something, and he was the type of arrogant, self-aggrandizing, utterly unworldly, Unix-bearded software-genius figure who wanted to create a programmatic universe all by himself.

Greg-Jim-Bob had never managed that feat, but he'd managed to create ClearWorks. That program had become a legend among its users. All the cognoscenti and digerati and designerati vied to praise ClearWorks. Of course, nobody actually used it. If you gave people the tools that were perfect for their jobs, they'd have nothing to do but their jobs.

The whole secret of the network revolution was that it connected everybody, and it therefore caused everybody to do everybody else's jobs.

It came to Yuri with a shock that ClearWorks did not interoperate. No. ClearWorks didn't even hook to the Internet. ClearWorks was a single tool for one single human mind. There was no crowdsourcing in it, no open-source collaboration, no "with enough eyes all bugs are shallow" … no add-ons, no plug-ins, no open application programming interfaces.

ClearWorks was a simple bone-white space for imagination.

Yuri couldn't believe the program was such a little sandbox. He could remember tackling ClearWorks as a student. At the time, he had felt the program was incredibly advanced: it was cosmic, infinite, awesome.

How had ClearWorks become such a tinkertoy?

Yuri shook his head and recalled his purpose. The task at hand was some conceptual proposal for a François Roebel temple. The maestro might ramble in from his nap at any minute, and Yuri had to show him something sure to snag his interest.

What the heck, any pastiche had to start somewhere: the Golden Rectangle. Always a sound choice: it never looked awkward no matter how it was used.

Bang, up it came, the good old Golden Rectangle, and then: boo000000ooom … that was the oldest,

purest joy of computer design: the effortless replication. Yuri gripped his little wand. Hook a twist on that series—a ram's-horn fractal thing …

What would the maestro do? Well, he'd do something off the wall that nevertheless seemed eerily necessary. Because despite his many personal quirks, Roebel was the true golden wizard of the rubrics of assemblage: "The parts grow out of the rules, while the rules grow out of the parts."

Insert a barrel vault. Who couldn't like barrel vaults? Especially intersecting barrel vaults. Multiple intersecting barrel vaults.

Yuri forgot himself. He forgot his purpose; he forgot where he was. The chair vanished and the screen became vapor. Yuri splashed in pure potentiality, free of care, liberated, purely enjoying himself …

Until it dawned on him that Roebel wasn't going to much care for this plan. The plan had a whole lot going on, but the plan wasn't very François Roebel.

Worse yet, the strict limits of ClearWorks were starting to bug Yuri. ClearWorks was a 30-year-old program. Furthermore, the whole shebang had been created by just one guy, and though he had made a really cool sandbox, it was pretty much nothing but sand.

Yuri had begun to sense the way the programmer thought. No geek from 30 years ago could ever think like a modern builder. Though he had a cunning intuitive arsenal of cool ways to assemble his sand, he lacked any cool ways to disassemble his sand.

It was as if he thought that real buildings went up in some Platonic cyberspace where gravity, friction, and entropy had never existed. Where the passage of the years was just an abstraction. The author of ClearWorks was pure geek, so he didn't realize that when you meshed bits and atoms, you had to respect the atoms. Bits were the servants of atoms. "Bits" were just bits of atoms.

Bits came and went at the flick of a switch, but atoms had deep and dark and permanent physical laws. Atoms didn't go away when you shut down the screen. When you lacked a responsible way to deal with the atoms, you were a menace to yourself and all around you.

Armed with this ethical knowledge, Yuri set to work to repair the oversight. Suddenly ClearWorks was fighting him all the way. To get ClearWorks to tear apart its own constructions, Yuri had to break its elements right down to their little, least, voxel-sized bricks.

Now Yuri really had a fight on his hands. The program had been mumbling along in its Wagnerian grandeur, all pale timeless majesty and the sonorous sawing of spatial strings—but Yuri's blood was up. He heard a Ride of the Valkyries in his mind's ear, a Götterdämmerung theme song … . He had to tear that pure simplicity apart.

Break! Decay! Come apart, you stupid Total Work of Art! Quit trying to hold yourself together in defiance of all sense and sanity! From pixels you are, and to pixels you shall return … .

Light clicked on overhead. Preston was standing at the doorway, a beer in hand. Somehow, day had become evening.

"Are you still at it in here?"

Yuri blinked. "Is it late?"

"Yeah, you've been in here for five solid hours!"

Yuri abandoned the office chair. Suddenly his back was killing him. "Where's François?"

"The clients woke him," said Preston. "We're feeding them cocktails over in the solarium—cocktails, and hogwash." Preston walked over and stared. "Wow."

"I tinkered around."

"That's looking pretty different. That's looking … pretty fresh."

"Design for disassembly," said Yuri. "I had to put it all on a kind of loop."

Preston watched the animated screen, absently sipping his beer.

"You know," he mused at last, "there is an aesthetic quality to old computer graphics that is truly haunting. It's very much like the scary, Gothic quality of silent film. Mankind will never be able to simulate buildings this badly again."

"I could work on the color tonalities."

"No, no, leave that, leave it!" Preston snatched the bat from Yuri's hand. "Did you use the cortico-cognitive headset?"

"What?"

"That neural brain-reading consciousness gizmo?"

"Oh, that," said Yuri. "It's funny, but I never even plugged that in."

"That instant brain reader was supposed to be extremely 'useful and convenient.'"

Yuri shrugged. "You can't step in the same river twice."

A stranger peered into Roebel's office, then stepped inside. He was young, nattily dressed in a tailored suit, and he carried a fancy valise.

"What have we here?" he said.

"You've found the old man's design office," Preston told him. "Yuri Lozano: Mark Quintaine. Mark is a local attorney."

Quintaine had an elegant haircut, a very practiced manner, and a slightly eccentric business suit. He

might also conceivably have been gay, but those were just his San Francisco regionalisms: oh, yeah, this guy was a real-estate lawyer, all right. Yuri had met so many that he could smell them by now.

The code and the law: they were two sister practices. One of them was logical, and humane, and rigorous, and the backbone of civilization. And the other was crazy, and snarled, and corrupted, and full of loopholes. And nobody could tell which was which.

Quintaine's nostrils flared as he stared around the office. There were holes in the sheetrock, and nobody had dusted the blinds. He jerked his thumb over his pin-striped shoulder. "Did he have to string the power cables right over the door frame? That's not very feng shui."

Preston was quick to sense a slight. "I wouldn't have guessed that the Church of Computer-Human Symbiosis was so into feng shui."

"I never speak ill of my clients," said Quintaine, "but after the five solid decades those geezers have spent immersed in game environments, Chinese set design is the least of their problems."

This was a charming remark, and despite the fact that the man was a lawyer, Yuri found himself won over.

"I take it you're not a member of the church."

"My parents were members of that church," said Quintaine. "They took me into every temple ever built by the maestro in there … they are all works of genius. But if you spend enough time in the presence of a wellnigh supernatural talent, it can get a little samey." He had been drinking. "I'm sure the world could do with another François Roebel masterpiece, though." Quintaine had a long, goggling look at the workstation's flickering screen. "My God in heaven! What has he done?"

"That's not a François Roebel masterpiece," said Yuri.

"Okay, I can see that, but what is that thing? It looks like a million giant ants are eating Notre Dame."

"It's a little something I just cooked up."

"You're an architect?"

"Once. Yeah."

Quintaine lifted a brow. "'Once'?"

"I don't call myself that. Not anymore."

This remark hit Quintaine hard. "I used to call myself a lawyer." He dropped into the office chair and stared at the busy screen. "It took me a while to figure it out: I don't practice law. I am a fixer. I practice all kinds of stuff: Urban politics. Acquiring properties. Managing upkeep. The piecemeal growth of holding funds. Sweeping problems under the rug for the time being—I'm required to do a whole lot of that."

"That sure sounds like the law to me," Yuri said.

Quintaine looked up. "But I don't have any human clients."

"Really?"

"It's true. My only true client is a large sum of money. And the way that wealth-management system was structured … well, it was so complex and restrictive that everybody ran away from it. Even the geeks who were supposed to own that wealth have fled into a fantasy world. That wealth is like some vast black bowling ball that rolls up and down Silicon Valley. Do you guys remember that word, 'silicon'?"

"I loved silicon," said Yuri.

"Oh, me too," said Preston with fervor. "Silicon used to be 25 percent of the planet's crust!"

"So I had it figured," said Quintaine, "that we would commission François Roebel and throw that 'Permanent Construction Fund' at him. Roebel is notorious for never completing any building on time or under budget. If you look at the way that construction fund was structured—well, we're a lot better off with fantastic, impossible, never-realized buildings. In today's sustainable economy, it's the total cost of ownership and the price of recycling that kill us."

"That's extremely interesting," said Yuri. "I hadn't heard a lawyer frame that issue like that before."

"California state law is always well ahead of the global and national curves."

"Yeah, that's right."

"Now that you've come up with this exciting proposal," said Quintaine, confronting the workstation, "I'm getting a brain wave. This plan here is not even a 'building,' as far as I can figure. The way the structure keeps looping around like that—that's a process that's permanently under construction and deconstruction. There's no final state where one has to legally sign off and accept ownership. So that's not a 'building,' legally speaking. That's a process. It's a process in permanent interoperation."

"Mr. Quintaine, you must be a pretty good lawyer."

Quintaine spun himself in the chair. "My firm has stopped calling itself a 'law firm,' actually. We've moved into another set of practices that are … well … much more contemporary."

Yuri shot a look at Preston. In a gesture so subtle as to be almost invisible, Preston brushed one finger against his lips.

"When you've lost control of the flow of events," Yuri told the mirror, "your duty is to hope and plan for happy accidents."

"Stop muttering and complaining so much," Gretchen told him. She adjusted his bow tie, for the third time. "You should try to enjoy your big night."

"I'm still rehearsing my big speech," said Yuri. He had read the critic's speech six times. Preston Mengies was finally back in top form, given that he had an exciting controversy to exploit. "Honey, that speech of his is a corker! It's full of raw meat for the interops crowd. I'm embarrassed to deliver a rant like that. Can I get away with it?"

"It's not a 'rant,' honey. They give you a major award, and you give them a major address. You have to rise to the occasion somehow. You can't pretend that you stole a cookie from the cookie jar."

Gretchen was dressed in a tawny-colored taffeta evening gown. Her hair was done, her painted face solemn, and she looked aggressively gorgeous.

This glamorous apparition, tidying him up and chivying him along and rolling him onto the stage: this was not Gretchen Lozano at her happiest. Gretchen looked toned, taut, tense, and very committed.

Gretchen was happy during summer camping trips in northern Michigan. A camping trip with Yuri, his two brothers, and his two sons: five howling, boisterous, dirty men all demanding that she gut and cook raw fish.

That made Gretchen happy. It took a situation that primeval to free Gretchen from her troubled, complex heritage. In the wilderness, Gretchen forgot all about her past traumas; instead, she griped cheerily about every new day's dirt, smoke, filth, scratches, blisters, and insect bites. In that drippy green wilderness, full of wolves, Canadians, and caribou, Gretchen ate like a horse, ran like a deer, and made love like a wildcat.

So he knew that Gretchen could be happy. And he knew how to make her happy. And there was a lot to be said for that.

This other kind of Gretchen Lozano, the woman at his shoulder tonight, was the scheming wife of a purported genius. Yuri's new construction was famous. It was a permanently unstable tower of plug-in plastic modules, all hemp, glue, and fly ash. And it rebuilt itself each and every night. This radically unstable, profoundly interactive, ever-shifting phenomenon was ironically named "The Monument." It was attracting hype in the way a puddle of honey drew flies.

The project's grand success had swiftly transformed Gretchen Lozano from a midwestern builder's wife into the elegant, high-society consort of a network-design superstar. Gretchen knew how to manage this. It was a quality that had been lurking inside her always, waiting to flicker into daylight.

Dressed for the banquet, Gretchen looked as sleek as a laser construction tool. She looked as if somebody could pick her up and use her nose to scratch plate glass.

"Preston knows that it was all just a lucky accident," Yuri said. "Preston is a smart guy; he was there when I did it. He knows I didn't really mean to do it."

"Oh, sure, it was all an accident, maestro. You're just one big fake, and so are the thousand rip-off artists trying to imitate you." Gretchen drew a breath within her décolletage. "People don't want to live in 'buildings' anymore, Yuri. People want to live inside construction programs. People are willing to pay top dollar to live in the way that modern people actually do live. That's no accident. We are rich and you are famous. Understand? Only a total sap could fail to understand that. And if you're too lazy and neurotic to live up to your potential, well, I'm going to beat you. I'm going to hit you on the head with a stick."

Gretchen had never spoken to him in that way—never before her father had died. It required his death to liberate her to echo him.

Tommy banged at the door and wandered into their bedroom. Tommy was 15 now, and shooting up like a weed, but in his dark, tailored suit he looked like a clockwork figurine. "Why are you two still standing around here? Can't we go yet? I'm starving."

Yuri wanted to spare him. "You really want to go to see some boring awards, Tommy? You could stay here and kill monsters with your little brother."

"Yeah, I gotta go to the banquet," Tommy said with a shrug. "Your building is great and all the other buildings suck rocks, Dad."

"It's that simple, huh?"

"Yeah—my dad can make cool buildings that aren't crap!"

"We'll be right along, Tommy," said Gretchen, heels clicking as she fetched her wrap. "You can have a snack in the limo."

Tommy left. Gretchen watched him go, then printed Yuri's cheek with a kiss-proofed lip. "'Some men are born great, and others have greatness thrust upon them.' If you're at a party and five friends say that you're drunk, then you're drunk. And you'd better go lie down. But if five million people say that you are a genius, you had better aspire to genius. You're not a drunk, honey. You could have been, but you got the other fate. You're going to be just great."

"That's your final word on this subject?"

"Okay, maybe one more word. I always knew you had this in you. I just hoped it wouldn't be too messy, when it finally came oozing out." TR

Bruce Sterling is an American novelist, journalist, and critic. He edited the seminal cyberpunk anthology Mirrorshades.

Reviews

Books, artifacts, reports, products, objects

SOCIAL COMPUTING

Trivial Pursuits

The mundane is the message. By Jason Pontin

Minutes before beginning this piece, I twittered, "At home in Boston, writing about Twitter one more time." Robert Scoble, author of the technology blog Scobleizer, wrote in Half Moon Bay, CA, "Life with Milan is definitely nuts. He wakes us up at 3 A.M. and we both look at each other and say 'good thing he's so damn cute.'" In San Francisco, Twitter cofounder Evan Williams wrote of cofounder Biz Stone, "Talking about Biz's need to get better at twittering." In Tokyo, someone named Shiru said, "ちょっとだけサーフィン上手くなってきた気がする仕事再開." ("I'm getting better at surfing. Okay, time to get back to work.")

On Pownce, Michael Owens, a 22-year-old graphic designer in Chicago, addressed himself sternly: "I need a way to force myself not to check social media and blogs and webcomics and all the other things that I get distracted by." A short time later, he posted, "Holy Crap. The Care Bears Movie is on. That's freaking awesome." And over at Facebook, Ed Vaizey, an old college friend who is now a member of the British parliament, told his 233 other friends about his professional reading: "Just read Robin Harris's biography of Talleyrand—superb; and Edward Pearce's biography of Walpole, not so good, far too arch."

WWW.TWITTER.COM
WWW.POWNCE.COM
WWW.JAIKU.COM
WWW.KYTE.TV
WWW.FACEBOOK.COM

These notes—terse, obscure, and endlessly self-referential—are all examples of a new phenomenon in social media called "microblogs": short electronic posts, sent to friends or to a more general community, that deliver some information about the sender. Sending microblogs broadcasts, "I am here!" Reading microblogs satisfies the craving of many people to know the smallest details of the lives of people in whom they are interested. Already, new-media intellectuals have coined a term to describe the new social behavior they say microblogging encourages: they talk of "presence," a shorthand for the idea that by using such tools, we can enjoy an "always on" virtual omnipresence.

As Kate Greene reports in her profile of Evan Williams, "What Is He Doing?" *(p. 44)*, ever since Twitter was named best blog at the Web Awards at the South by Southwest festival in March 2007, the number of people using the microblogging service has expanded swiftly. In March, Twitter had 100,000 members, according to Biz Stone; today, TwitDir.com, an independent Twitter directory, says there are almost 500,000 twitterers. But the most obvious signal of microblogging's importance is the swelling number of Twitter peers or imitators. Recently, a Chinese blog counted around 100 "Twitter clones" in at least 12 countries. They all have cute, telegraphic names: Jaiku, Kyte, Plazes, Pownce, Yappd. Even Facebook has joined the trend. The smartest of the social networks now allows its users to send their friends short posts that describe their "status."

Two services merit attention: Twitter, because it was the first and is the best known, and Pownce, because of its many features and the personality of its founder, Kevin Rose.

Twitterers use mobile phones, instant-messaging software, or Twitter's own website to send and receive 140-character messages, called twitters or tweets. Tweets—which mostly answer Twitter's prompt "What are you doing?"—are routed to individual friends, to networks of friends, or to everyone who registers with Twitter.

Most twitterers (or twits, as they are sometimes inevitably called) communicate with small networks of people they know, but the most loved have thousands of people who "follow" them (to use Twitter's own jargon). Paul Terry Walhus, a developer from Austin, TX, had 2,421 friends as of late September. Robert Scoble, the technology blogger, had 5,880. John Edwards—*the* John Edwards—had 3,528.

But as Evan Williams told me, "Celebrity twitterers are really outliers, even though they get a lot of attention." Williams believes that the service is best understood as a system that swiftly routes messages, composed on a variety of devices, to the people who have elected to receive them, in the media they prefer.

JULIETTE BORDA

Twitter's elegance lies in its extreme simplicity. Pownce is more complex. As with Twitter, one can send messages to friends or groups of friends as well as to the service's general community. (Unlike Twitter's messages, Pownce's cannot be sent to mobile phones.) But you can also send your friends links, invitations to events, photos, pieces of music, or videos. In addition, you can finely discriminate which group or subgroup of friends will receive a particular post. It is this combination of private messaging and file sharing that makes Pownce seem so richly functional. Such features are more often found on fully formed social networks like Facebook; but Pownce retains much of the intimacy and directness of Twitter.

Pownce was cofounded by Kevin Rose, the cofounder and chief architect of the hugely popular news aggregation site Digg and the cofounder of Revision3, an online video production and hosting company that shoots *Diggnation*, a weekly news show that Rose cohosts. Much of the excitement that attended the launch of Pownce last June derived from Rose's reputation for creating new-media companies that hypnotize their youthful audiences into cultish devotion. Pownce seemed especially cool because Rose decided that only those with invitations would be permitted to test the new site.

Most of the other microblogging services combine some features of both Twitter and Pownce. Jaiku, for instance, works with cell phones, as Twitter does, but like Pownce, it is more friendly to pictures and videos. A few have novel variations on the basic themes: Kyte grandly claims that it allows "anybody to create their own interactive TV channel on their Website, blog, social network, or mobile phone"—a kind of microblogging that bypasses the written medium altogether.

Critics of microblogging argue that the services are not sustainable businesses, because they merely float upon the speculative bubble of venture capital investment in Web 2.0 companies. More nastily, they complain that almost all microblog posts are stupefyingly banal.

Bruce Sterling, the journalist and science fiction writer (whose latest short story can be found on page 69), crisply articulated the latter argument when he wrote to me, "Using Twitter for literate communications is about as likely as firing up a CB radio and hearing some guy recite the *Iliad*." The private-equity markets best express the first argument: while the microblogging sites could not exist without venture capital, the sums invested in them have been relatively small. (Twitter, for instance, reportedly received about $5 million from Union Square Ventures and other investors, a paltry figure for a company whose importance has been so hyperbolized by the media, bloggers, and its users.)

But it's too soon to dismiss the microblogging services' potential as businesses. Although all offer free registration, they could charge their customers and communications companies for premium functions. Pownce already charges its users for the ability to send large files. Perhaps the wireless

carriers might pay the services to act as application providers for their customers; when mobile-telephone users bought a plan, they could select Jaiku as an option. Another possible source of income could be advertising that is pertinent to a particular user; advertisers and the media buyers at advertising agencies, for all their disenchantment with print publications and broadcast media, will still spend good money for the type of effective, targeted advertising offered by Google AdWords and AdSense. Finally, the services could be used for direct marketing. Already, a few companies (including Twitter itself) are using microblogs to directly market themselves; since users don't receive promotional posts unless they've chosen to receive them from the corporations they follow, the blasts are presumably welcomed.

My own experiments posting semiregularly on Twitter and Pownce produced mixed emotions. I quickly realized that decrying the banality of microblogs missed their very point. As Evan Williams puts it, "It's understandable that you should look at someone's twitter that you don't know and wonder why it should be interesting." But the only people who might be interested in my microblogs—apart from 15 obsessive Pontin followers on Twitter—were precisely those who would be entertained and comforted by their triviality: my family and close friends. For my part, I found that the ease with which I could communicate with those I love encouraged a blithe chattiness that particularly alarmed my aged parents. They hadn't heard so much from me in years.

On the other hand, I strongly disliked the radical self-exposure of Twitter. I wasn't sure it was good for my intimates to know so much about my smallest thoughts or movements, or healthy for me to tell them. A little secretiveness is a necessary lubricant in our social relations. TR

Jason Pontin is the editor in chief of Technology Review.

MEDICINE

A Genetic Test for Diabetes Risk

New tests that detect genes for common diseases are reaching the consumer market. But will they help make people healthier?

By Emily Singer

When I was a destitute graduate student several years ago, I decided to earn a quick $75 by signing up for what sounded like a relatively innocuous clinical study. An I.V. in my left arm would feed precise amounts of glucose and insulin into my bloodstream, while from my right arm a nurse would periodically draw blood to test for glucose. The study would assess how effectively my body responded to sugar, a measure that predicts risk for developing type 2 diabetes.

DECODE T2 DIABETES TEST
DNA Direct
$500.00, dnadirect.com

As someone with a family history of the disease, I had long had a shapeless fear of it. A phone call from the nurse a few days later turned that vague anxiety into something much more concrete. The blood tests showed I was "insulin resistant," meaning that my muscle, fat, and liver cells were not responding to insulin as efficiently as they should—significantly boosting my risk of diabetes.

About 20.8 million people in the United States have diabetes, and another 50 million or more are at risk. Although the onset of the disease can be delayed—sometimes even prevented—with diet and exercise, efforts by doctors and public-health agencies to encourage healthy habits are making marginal progress at best.

In the last several months, however, a potential new tool for diabetes prevention has come to market. A test developed by the Icelandic genomics company deCode Genetics and marketed to consumers by San Francisco–based DNA Direct determines whether people carry copies of a genetic variation that can greatly increase the risk of developing type 2 diabetes. It's available for $500 through a website,

POLLY BECKER

and DNA Direct's marketing material suggests that positive results will give people extra motivation to get fit. But critics say there is no evidence that this test will succeed where so many public-health efforts have failed.

Worth It?

Diabetes is the result of a complex mix of genetic and environmental factors. But recent genomic studies have identified several genetic variations that contribute heavily to the disease. The one that exerts by far the biggest influence occurs in a gene called *TCF7L2*, which was discovered by scientists at deCode in 2005; almost 20 percent of people with type 2 diabetes carry two copies of the high-risk version of the gene. These people are thought to secrete less insulin, a crucial hormone that signals cells to store glucose for energy. A single copy of the variation somewhat increases the risk of contracting the disease, and two copies double the risk, regardless of other risk factors.

The most likely customers for the new test are people with a family histories of the disease, like me, or early warning signs such as high blood sugar, says Ryan Phelan, founder and CEO of DNA Direct. And preliminary evidence suggests that people who already have diabetes might benefit as well: research presented at a conference this year found that people with the high-risk genetic variant are less likely to respond to a class of drugs that includes some of the most commonly prescribed treatments for type 2 diabetes.

But for people who don't have diabetes, doctors' advice would be the same whether the test came back positive or negative: maintain a healthy weight, and exercise. So what's the point of testing? "If they know they're at an increased risk, they will be motivated toward stronger interventions, be it losing weight or quitting smoking," says Phelan.

Not everyone agrees. David Altshuler, a geneticist at Harvard and MIT's Broad Institute for genomic medicine in Cambridge, MA, and a physician who treats diabetes patients at Massachusetts General Hospital in Boston, was one of the researchers who reported in the *New England Journal of Medicine* last year that among people considered prediabetic—meaning their blood sugar was high but not within the diabetic range—those with the high-risk variant of *TCF7L2* were more likely to develop diabetes than those with the normal version. The researchers also found that exercise and diet could slow or prevent onset of the disease, regardless of a person's genetic status. Yet Altshuler says he would not recommend the test to his patients. He says that although it appears to be accurate—the variation has been linked to type 2 diabetes in multiple populations—"there is no evidence that this genetic test does result in an improved health outcome." Highlighting patients' other risk factors, such as body mass index, often fails to inspire lifestyle changes, he points out, and it's not clear that a piece of genetic information will be any different.

Altshuler also worries that the test could have unintended consequences. Someone who turns out to lack the high-risk variation might slip into unhealthy habits, he says. Other critics have suggested that positive results might instill in their bearers a sort of genetic fatalism, giving them an excuse not to diet and exercise because diabetes is already written into their genes.

Given the uncertainty about the test's impact, Altshuler argues that it's too soon to market it to consumers. He suggests that, like drugs, genetic diagnostics should undergo clinical trials to prove their effectiveness. "If it turns out that people given this information reduce their risk of diabetes in a cost-effective way, I'm all for it," he says. "On the other hand, $500 is a lot to spend if no good comes of it."

But deCode CEO Kári Stefánsson, thinks it's time to make the test available. "Once you have discovered a sequence variant [linked to disease]," he says, "you could make the moral argument that people who want to know have the right to do so."

Getting Personal

While many genetic tests are already commercially available or in the works, deCode's is the first to assess risk for a common disease that many people can relatively easily prevent or delay. People with family histories of certain cancers can undergo tests that detect mutations linked to those diseases, but the recommended interventions can be as drastic as preëmptive mastectomy. Scientists have also identified a genetic variant linked to increased risk of Alzheimer's disease, but in that case, there are no recommended interventions at all.

The deCode diabetes test could be a bellwether for diagnostics that predict risk of heart disease, hypertension, and other problems that can be ameliorated by lifestyle changes. "This test is an example of the direction we're headed over time," says Benjamin Wilfond, an ethicist who studies genetic testing at the University of Washington School of Medicine in Seattle. "This is potentially the sort of information that would be relevant to everyone."

But as Altshuler points out, we have little information on whether people really do make lifestyle changes in response to genetic tests. And the few studies that have been done are not encouraging.

People, it seems, don't want to hear bad news—or they simply ignore it. In one study of smokers, scientists found that those who tested positive for a genetic variant that increased their risk of developing lung cancer were more likely to have forgotten the result six months later than those who tested negative. And preliminary results from a study sponsored by the National Institutes of Health suggest that healthy people aren't particularly interested in this type of testing. In the study, scientists offer healthy people a

prototype test that detects 15 genetic variants implicated in eight common health conditions, including diabetes, heart disease, high blood pressure, and lung cancer—all of which can be prevented or delayed by changes in lifestyle. But so far, only about 10 percent of those approached have chosen to take it. "We think they don't see themselves as particularly vulnerable," says Colleen McBride, a scientist at the National Human Genome Research Institute and the study's leader.

If healthy people got interested in genetic testing, they would probably be the group to benefit most. If they were found to be at high risk, they could try to prevent even the first signs of disease. "Right now, we can't get on the radar screen of healthy, young individuals because they don't see themselves as susceptible to diseases that occur later in life," says McBride. But new genetic tests "might be the kick start they need to engage them in the process," she says. "The more personal the risk is, the more likely they are to react to it."

When I first learned about my own risk for diabetes, I began exercising religiously and viewed white flour and sugar with suspicion, with the result that I dropped 30 pounds. Since then, my blood sugar tests have all been normal. As a result, my vigilance waned. That's why I decided to order the test, which is almost as easy as buying a book from Amazon: a credit card and the time to answer a quick questionnaire about family history and other risk factors are all it takes. I sent in my DNA-coated swabs a few weeks ago and am awaiting my results. I realize that I'll need to keep exercising and eating right regardless, but I want to know anyway, partly out of curiosity—a positive result could explain my own lengthy family history of diabetes—and partly because I think that for me, a positive result will provide extra motivation. Every little bit counts. TR

Emily Singer is the biotechnology and life sciences editor of Technology Review.

LAW

The Talk of the Town: You

Rethinking privacy in an immodest age. By Mark Williams

Earlier this year, *New York* magazine published a long piece called "Say Everything." Subtitled "Kids, the Internet, and the End of Privacy: The Greatest Generation Gap Since Rock and Roll," the piece breathlessly revealed that about 60 percent of modern American youth already have their biographical details and images online at MySpace, Facebook, YouTube, or similar social-networking websites. *New York*'s reporter made a big deal about how "the kids" made her "feel very, very old." Not only did they casually accept that the record of their lives could be Googled by anyone at any time, but they also tended to think of themselves as having an audience. Some even considered their elders' expectations about privacy to be a weird, old-fogey thing—a narcissistic hangup. One teenage girl was asked about cases in which sexual material featuring girls her own age had been posted on the Internet without the subjects' permission. "It's either documented online for other people to see or it's not, but either way you're still doing it," the girl replied. "So my philosophy is, why hide it?"

THE FUTURE OF REPUTATION: GOSSIP, RUMOR, AND PRIVACY ON THE INTERNET
By Daniel J. Solove
Yale University Press, 2007, $24.00

Some prominent technologists have arrived at roughly the same conclusion—if a little more reluctantly. As Sun Microsystems chairman Scott McNealy put it in 1999, "You have zero privacy anyway. Get over it." The view that surveillance is already ubiquitous led David Brin to argue, in his 1998 book *The Transparent Society*, that our only real choice is between a society that offers the illusion of privacy, by restricting the power of surveillance to those in power, and one where the masses have it too. Brin prefers the latter.

If we don't like that conclusion, we may gravitate to the opposite pole: the absolutism of organizations like the Electronic Privacy Information Center, the Electronic Frontier Foundation, and the ACLU, which tend to construe any collection and analysis of personal data by government agencies (and to a lesser extent by corporations) as potentially violating the U.S. Constitution's Fourth Amendment guarantee of citizens' rights "to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures."

But these two positions may feel, even to their proponents, more theoretical than practicable. Happily, *The Future of Reputation: Gossip, Rumor, and Privacy on the Internet*, by Daniel J. Solove, associate professor of law at the George Washington University Law School, offers alternatives.

The book isn't much concerned with privacy advocates' usual bête noire, the surveillance state. Instead, Solove focuses on a more down-to-earth set of concerns. Nowadays, thanks to Marshall McLuhan, we're accustomed to talking about the "global village." But traditionally, in villages, everybody knew everybody else's business; personal privacy and anonymity are social constructs that achieved their current legitimacy when increasing numbers of people started moving to cities in the 18th and 19th centuries. Nonetheless, privacy remains simply, as Columbia University professor emeritus of public law Alan F. Westin has phrased it, "the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about them is communicated

to others." That claim had far less authority in the smaller communities in which most people once lived, and those communities had greater power to enforce social norms by enhancing or destroying reputations. In 1910, writer John Jay Chapman testified eloquently to the extent of that power: "If a man can resist the influences of his townsfolk, if he can cut free from the tyranny of neighborhood gossip, the world has no terrors for him; there is no second inquisition."

And yet, as Solove points out, the current state of the Internet allows townsfolk to be nearly lethal. For one example of the inquisitorial possibilities presented by the digital global village, he suggests, consider the young woman who let her small dog crap on the floor of a South Korean subway train in 2005 and then ignored other passengers who told her to clean up the mess. Somebody took pictures and posted them on a blog. Within hours, the photos were on dozens of other blogs; within days, the young woman had been identified, the story had reached Korea's mainstream media, and millions knew her as gae-ttong-nyue, or "dog poop girl." In response, she dropped out of her university.

Or take the case of Jessica Cutler, a junior staffer for a U.S. senator, who began blogging in 2004 as the Washingtonienne. According to Solove, Cutler's blog "described daily adventures … which consisted of a lot of partying with various men." The blog featured a revolving cast of a half-dozen of these, and Cutler wrote sexually graphic commentary about her exploits with them. A much-read Beltway gossip blog called Wonkette soon linked to Cutler. The resulting notoriety got Cutler fired, but it also attracted the likes of the *Washington Post*, the *New York Times*, and CNN, and earned her a $300,000 book contract and a *Playboy* photo shoot. Things went less swimmingly, Solove observes, for one of Cutler's former boyfriends, a DC lawyer, who'd had no idea that her accounts of their trysts had been appearing on the Internet. Cutler had used his initials and mentioned that he worked for the same senator that she did, making his identity—and his spanking fetish—quite clear. "RS" left his job and launched suits against Cutler for invasion of privacy. The wrangling is being watched by privacy groups for the precedents it may establish about whether bloggers are obligated to protect the privacy of those they discuss. Solove points out that balancing the right to privacy against the First Amendment's guarantee of free speech has always been problematic; Cutler's case, however amusing, shows that the Internet has made that dilemma even more acute.

ROBERT JONES/ARCANGEL IMAGES

Solove describes the spectrum of sites set up to tarnish reputations. At the lighter end is Bitterwaitress.com, with its searchable "Shitty Tipper Database," which contains alleged culprits' names and their rankings as cheapskates. Sites such as Don't Date Him Girl have greater potential to harm the people they profile. And on the dark end of the spectrum are fringe sites like the Nuremberg Files, which profiles doctors who perform abortions. Until it was forced to stop doing so, it listed those wounded by antiabortion activists in gray type and put a line through the names of those who'd been killed.

Solove sees an expanded role for law here, but he disapproves of authoritarian legislation that attempts to ban specific kinds of speech or activity. He also thinks that although people who feel abused online can and should have recourse to tort, defamation, and privacy law, each of these areas needs reconsideration. Before being allowed to proceed with litigation, he suggests, plaintiffs could be compelled to prove, first, that they sought redress outside court, and second, either that the defendants refused to remove harmful material or that the damage done was severe and irreparable.

Beneath Solove's legal suggestions rests a keen insight about the extent to which the Internet changes basic questions about privacy. Traditionally, Solove reminds us, the law's view of privacy has been binary: if somebody is filmed in public, that person is deemed to have had no reasonable expectation of privacy; anyone who really wanted privacy, the law generally says, should have stayed home. Similarly, if somebody communicates confidential information—that he's HIV-positive, say—to a trusted circle of 50-odd acquaintances, and one of them then conveys the facts beyond that circle, the law makes it difficult to sue for breach of confidentiality. Solove believes it should be harder for someone to betray trust in that kind of situation, and he proposes using social-network theory, which analyzes social relationships in terms of nodes (individual actors within a network) and ties (the relationships between those actors), to determine when a reasonable expectation of privacy exists.

Solove's proposals in *The Future of Reputation*, if tried, might work or fail. They have the virtue, at least, of giving us something to think about beyond the old binary view of privacy, which is too blunt and dysfunctional to address privacy in the Internet era. TR

Mark Williams is a Technology Review *contributing editor.*

Virus-Built Electronics

Assembling nanomaterials with the help of innocuous viruses could lead to threadlike batteries and photovoltaics that can be woven into clothing.

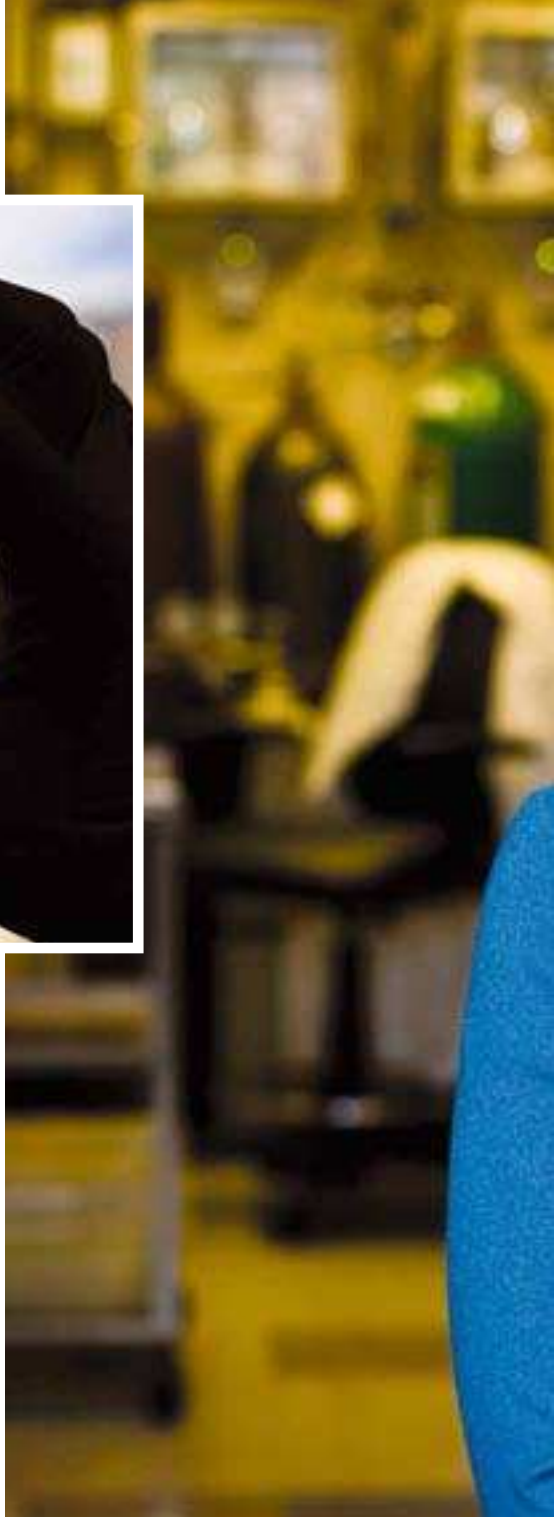
By Kevin Bullis

Angela Belcher leans in to watch as a machine presses down slowly on the plunger of a syringe, injecting a billion harmless viruses into a clear liquid. Instead of diffusing into the solution as they escape the needle, the viruses cling together, forming a wispy white fiber that's several centimeters long and about as strong as a strand of nylon. A graduate student, Chung-Yi Chiang, fishes it out with a pair of tweezers. Then he holds it up to an ultraviolet light, and the fiber begins to glow bright red.

In producing this novel fiber, the researchers have demonstrated a completely new way of making nanomaterials, one that uses viruses as microscopic building blocks. Belcher, a professor of materials science and biological engineering at MIT, says the approach has two main advantages. First, in high concentrations the viruses tend to organize themselves, lining up side by side to form an orderly pattern. Second, the viruses can be genetically engineered to bind to and organize inorganic materials such as those used in battery electrodes, transistors, and solar cells. The programmed viruses coat themselves with the materials and then, by aligning with other viruses, assemble into crystalline structures useful for making high-performance devices.

But the approach is not just an alternative way to make familiar devices; it could also be the impetus for developing entirely new ones. In past work, Belcher has created virus-based thin films for rechargeable batteries. Now that she can spin viruses into fibers, she envisions threadlike batteries and other electronic devices that can be woven directly into clothing. "It's not really analogous to anything that's done now," she says. "It's about giving totally new kinds of functionalities to fibers."

The virus-based fibers have caught the attention of U.S. Army researchers. They hope to incorporate future versions of the fibers into uniforms, weaving them into the fabric along with other supporting materials. The resulting fabrics could have an array of advanced capabilities. Clothing made with them could sense agents of chemical and biological warfare; it might also store energy from the sun and power portable electronic devices, such as night-vision gear. Charlene Mello, a macromolecular scientist at the Natick Soldier Research, Development, and Engineering Center in Natick, MA, says that while such uniforms will probably take decades to develop, Belcher's work has paved the way for them.



Spinning Viruses

Belcher uses different procedures to make different kinds of virus fibers. To make the glowing fibers, she first used conventional genetic-engineering methods to modify the virus DNA so that one of the proteins that make up the body of the virus has extra copies of a specific amino acid at one end. At the same time, the researchers synthesized quantum dots (semiconductor nanocrystals that emit intense light at precisely tuned

PHOTOGRAPHS BY PORTER GIFFORD

TINY BUILDING BLOCKS **Angela Belcher (center) is using genetically engineered viruses to help synthesize useful nanomaterials. A small vial (left) contains a billion viruses, each with a slightly different genetic modification. These can be screened to determine which of them will bind to specific inorganic materials, such as those used in rechargeable batteries. Belcher and graduate student Chung-Yi Chiang (top right) watch as modified viruses are injected into a solution, where they assemble themselves into fibers. Chiang (bottom right) extracts one of the fibers from the solution.**

wavelengths) with surface amine groups that bind to the overproduced amino acid. The result: hundreds of quantum dots glommed onto each virus, which combined with similar viral particles to form a fiber that emits light.

Often, however, it's not obvious how to make a virus bind to specific inorganic materials, such as gold particles. In these situations, Belcher uses a method sometimes called "directed evolution," which allows her to quickly modify viruses to work with a range of materials.

In this case, directed evolution begins with a small vial that Chiang pulls from a refrigerator. Inside is a clear fluid that contains a billion viruses; they are nearly identical, but each has a subtle genetic variation introduced by the researchers. The variations are, in part, fortuitous: the researchers add a randomly generated sequence of DNA to each virus. But the added DNA, which codes for a short strand of amino acids called a peptide, is inserted into the gene for a select protein. Since there are so many variations among the viruses in the vial, some of them should randomly have peptides that bind to a useful inorganic material. The researchers simply pour the contents of the vial onto a target material, such as a small square of gold, and give the viruses a chance to bind. Then they wash the material.

STRENGTH TEST **Under ultraviolet light (above), a fiber made of genetically engineered viruses that bind to cadmium selenide nanocrystals glows red. A fiber made of unmodified viruses appears blue. Virus-based fibers could be used in sensors and other applications. At top right, Chung-Yi Chiang prepares a fiber for mechanical testing. Stretch tests (bottom right) confirm that the fiber is strong enough to be woven into clothing.**

After a few repetitions, only the viruses that happen to bind strongly remain. The process allows the researchers to quickly engineer viruses to bind to a particular material, even if they don't know ahead of time what sequence of amino acids is likely to work.

Once the right viruses have been made, getting them to form a fiber is relatively simple. First, the researchers concentrate the viruses so that their shape and chemical properties induce them to pack closely together in a crystalline pattern. Then they force the viruses through a needle and into a solution—a conventional process, called spinning, that helps determine the diameter of the fiber. After leaving the needle, the closely packed viruses tend to hold together. But to further strengthen the fiber, the researchers add a chemical linking agent to the solution; this agent binds neighboring viruses to each other. The desired inorganic materials can be added either before or after the fiber is formed.

Encouraged by their success with the quantum-dot-studded glowing fibers, Belcher and her coworkers hope to show that similar fibers can be made into, among other things, sensors, solar cells, and batteries. For example, they envision engineering two types of virus fibers, one that serves as a negative battery electrode and another that serves as a positive electrode. These fibers could be twisted together, with a polymer electrolyte between them, to make a rechargeable battery that could be woven into clothes.

Hurdles remain to be cleared, of course, before the technique will yield complex practical devices. For one thing, Belcher will need to invent fibers that do more than just glow red. But her methods make it relatively easy to try out different materials and new designs. The simple virus, says Belcher, gives her a great deal of flexibility. "It's just a wonderful unit," she says. "Nature gives you the perfect starting material." TR

Kevin Bullis is the nanotechnology and materials science editor of Technology Review.

Alumni-to-Alumni Directory

Recruitment

EDELMAN & ASSOCIATES Executive search and technical recruiting for software, biotech, pharmaceutical, and other high-technology companies.
Paul Edelman '78 paul@edeltech.com 508-947-5300
To see a listing of current searches, please visit us at www.edeltech.com.
For confidential consideration, send your résumé to paul@edeltech.com.

Classifieds

Siemens Water Technologies, a supplier of water/wastewater treatment equipment, is looking for a manager of technology development. This position will manage a group of engineers and scientists to advance electrode ionization, electrodialysis, and other electrochemical processes. Individual to become technology expert in this field, support other R&D groups such as Product and Development, and manage patent portfolio for the organization. Position requires individual with a long-term vision to lead dynamic, visible R&D group within a technology-oriented company. Must have MS or PhD in chemical engineering/chemistry. Minimum seven years' experience in industry or academia required. Knowledge of ion exchange membranes/resins and water treatment technologies a plus.
Apply online at
www.siemens.com/water
Jobs & Careers, Job #59473

A BETTER MOUSETRAP!
MIT-educated technologists will invent and develop it for you.
781-862-0200 www.weinvent.com

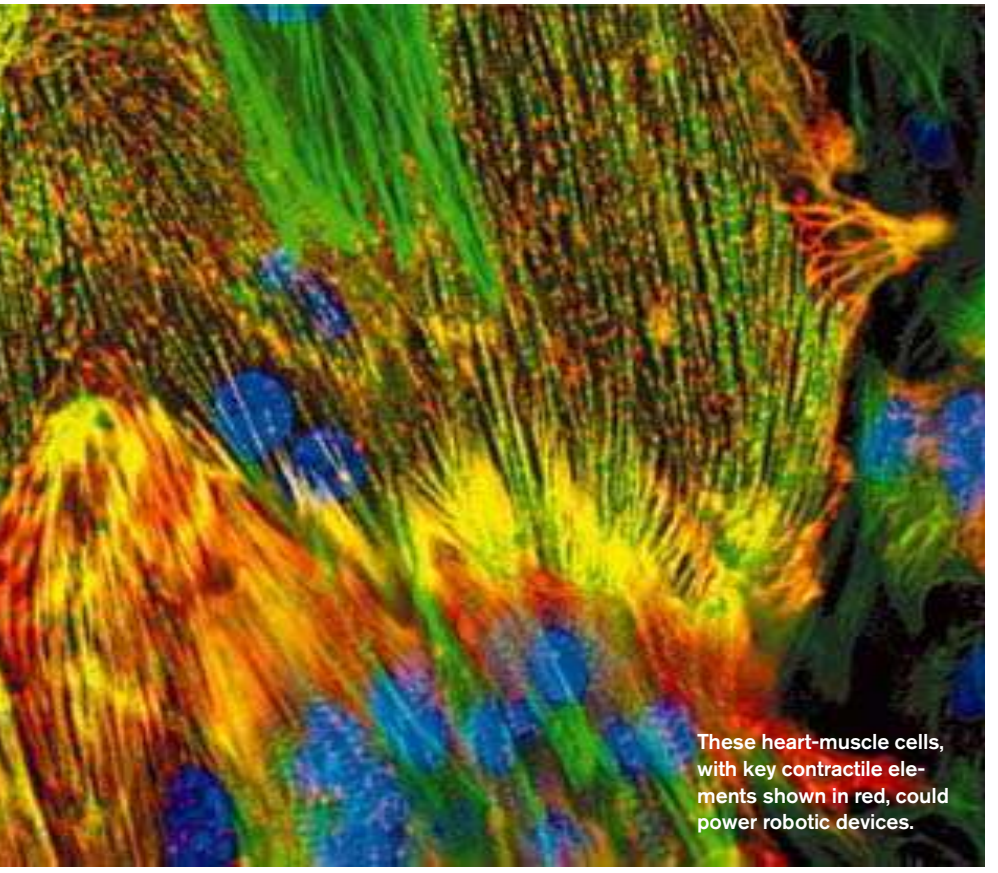
MIT Alumnus Mortgage Broker
20 years' serious experience
Lowest rates on large loans
Complicated deals made easy
All products available
Nick Adams SB XV 1981
Direct # 617-448-4081

SMART IS SEXY
FREE MEMBERSHIPS ARE SEXY TOO
Get your free membership in the introduction network for single graduates, faculty, and students of MIT and other highly ranked universities.
Use coupon code MIT2007
(limited time offer)
www.rightstuffdating.com
(800) 988-5288

CLASSIFIED & ALUMNI DIRECTORY ADVERTISING
For more information on classified or recruitment display advertising, contact:
advertising@technologyreview.com

From the Labs

Current research in nanotechnology, information technology, and biotechnology



These heart-muscle cells, with key contractile elements shown in red, could power robotic devices.

NANOTECHNOLOGY

Nano LEDs

Glowing nanowires could speed up computer processors and telecommunications networks

SOURCE: "Electrically Excited Infrared Emission from InN Nanowire Transistors"
Jia Chen et al.
Nano Letters 7: 2276–2280

RESULTS: IBM researchers have demonstrated a new technique for converting electricity into infrared light in indium nitride nanowires. Previously, getting a nanowire to emit light required injecting it with both electrons and "holes"—a physicist's shorthand for the absence of an electron. (An electron that leaps to fill a hole may leave another hole behind it; in this sense, the hole can be seen as moving.) Since the new technique requires only the injection of electrons, it is simpler and potentially more efficient.

WHY IT MATTERS: Light-emitting nanowires could be integrated into the microchips used in telecommunications. They could also be used for optical communication between devices on computer chips, which could significantly improve processing speed. Infrared light, which has previously been difficult to produce in nanowires, is ideal for use in silicon-based chips, the industry standard. What's more, the electron-only injection method yields light emitters that are brighter and more efficient than other nanowire devices.

METHODS: The researchers grew indium nitride nanowires by combining indium and indium oxide with ammonia at 700 °C. The nanowires, which were suspended in rubbing alcohol, were then dispersed over a silicon wafer patterned with electrodes. The wires bridged the electrodes, forming transistorlike devices. A current delivered by the electrodes caused the nanowires to emit light.

NEXT STEPS: Using these light-emitting nanowires in microchips will require methods for arranging nanowires into complex circuits at high speeds.

Muscle-Powered Devices

Novel machines could improve drug testing and lead to new kinds of robots

SOURCE: "Muscular Thin Films for Building Actuators and Powering Devices"
George M. Whitesides, Kevin Kit Parker, et al.
Science 317: 1366–1370

RESULTS: Researchers at Harvard University have made several small mechanical devices powered by heart muscle harvested from rats. The creations include pumps, a device that "walks," and one that swims.

WHY IT MATTERS: The scientists made the machines to study the behavior of muscles and to provide a plat-

KEVIN KIT PARKER, HARVARD UNIVERSITY

form for testing heart drugs. (The devices provide an easy way to monitor the effect of drugs on heart tissue.) Eventually, they could be used in new types of robots that can change shape, grip objects, and propel themselves.

METHODS: The researchers used a fabrication method called spin coating to make ultrathin elastic films; then they applied patterns of proteins to the films. Finally, they added heart-muscle cells; guided by the protein patterns, the cells organized themselves into working muscle tissue. To make the various devices, the researchers cut the muscular thin films into specific shapes (such as a triangle that resembled a fish's tail) and changed the alignment of the cells. The devices, which must remain in a solution that keeps the muscles alive, can be controlled by electronic signals sent through the solution.

NEXT STEPS: The researchers are working to create devices that use human muscle tissue, perhaps grown from stem cells; such devices could be used in drug testing or to patch damaged heart muscle. So far, the muscle tissue survives for only a few weeks. For robotics applications, the scientists may combine heart muscle with other types of cells to increase longevity.

INFORMATION TECHNOLOGY

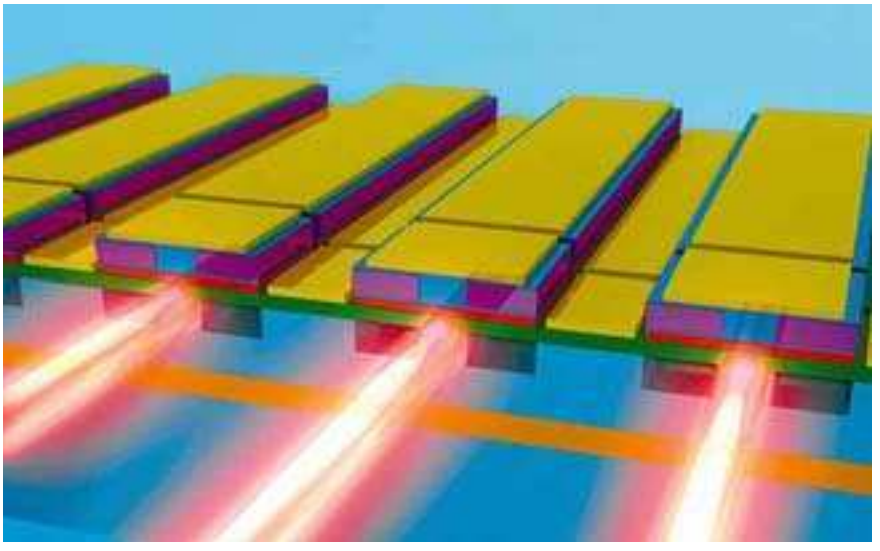
Faster Silicon Laser

A new design could yield a more practical light source for telecommunications networks

SOURCE: "Mode-Locked Silicon Evanescent Lasers"
Brian R. Koch et al.
Optics Express 15: 11225–11233

RESULTS: Researchers have designed a stable, electrically pumped silicon-based laser that emits ultrashort pulses of light at a frequency of 40 gigahertz.

WHY IT MATTERS: In modern telecommunications networks, bits of information are carried by laser light. Currently, the lasers that generate the light are made in dedicated indium phosphorous clean rooms. Silicon-based lasers that could be made on existing high-volume semiconductor manufacturing lines would be much cheaper. Until now, silicon lasers have been incapable of emitting pulses of light that are short enough and have high enough frequencies for use in telecommunications networks. The researchers hope that the new silicon-based device could replace the costlier lasers now used in optical networks.



This image depicts a new design for hybrid silicon lasers. Prototypes of the lasers are fast enough for use in telecom networks.

METHODS: The construction of the device begins with a wafer in which a layer of silicon dioxide is sandwiched between two layers of silicon. In the top layer of silicon, the researchers etch a channel called a waveguide. To the top of the wafer they bond strips of indium phosphide; when current is applied to electrical contacts, the strips emit light that bounces back and forth inside the waveguide. A small amount of the light sneaks back into the indium phosphide, where it is amplified and emerges as laser light. In order to control the pulses of light emitted by the laser, the researchers had to make sure that the waveguides were of a precise length, and that light-amplifying and light-absorbing regions of the device were electrically isolated from each other.

NEXT STEPS: Currently, the laser's performance drops at the high temperatures that can be characteristic of network hardware. The researchers need to modify the device so it can withstand these temperatures, and it will have to pass other tests of robustness. In addition, the researchers are exploring the best way to combine the laser with other components, such as modulators, to make silicon-based photonic chips.

Why Wi-Fi Fails

A diagnostic system determines where and why buildingwide systems falter

SOURCE: "Automating Cross-Layer Diagnosis of Enterprise Wireless Networks"
Yu-Chung Cheng et al.
Proceedings of the ACM Sigcomm Conference, Kyoto, Japan, August 2007

RESULTS: Researchers at the University of California, San Diego, have developed a system that tracks wireless traffic in a building and determines precisely what causes signals to dip, traffic to slow, and laptops to get kicked off the network.

PETER ALLEN, UNIVERSITY OF CALIFORNIA, SANTA BARBARA

WHY IT MATTERS: Wi-Fi tends to be unreliable. A number of factors can interfere with a signal, from hardware malfunctions and software bugs to interference from microwave ovens and cordless phones. What's more, the degree of influence these factors have can change quickly, making Wi-Fi failures difficult to anticipate and diagnose. An efficient way to pinpoint problems would make them much easier to correct.

METHODS: The researchers installed 192 radios to monitor traffic throughout the university's computer science building. To infer wireless activity that wasn't measured directly, they developed novel algorithms that extracted clues from the measured data. Using both the measured and the inferred data, they were able to determine how much each interfering factor contributed to Wi-Fi problems. The researchers think the technology could be implemented quickly. They say manufacturers could easily equip routers with traffic-monitoring hardware, along with software that analyzes network activity.

NEXT STEPS: The researchers will explore the technical challenges of deploying the system and maintaining constant network analysis.

BIOTECHNOLOGY

Glowing from Within

A new fluorescent marker illuminates tissue deep within living animals

SOURCE: "Bright Far-Red Fluorescent Protein for Whole-Body Imaging"
Dmitriy Chudakov et al.
Nature Methods 4: 741–746

RESULTS: Using genetic-engineering techniques, scientists have altered a red protein found in sea anemones to create a fluorescent marker that can be used to study living tissue deep in the body.

Scientists engineered this three-month-old frog to make a new fluorescent protein in its muscle tissues.

WHY IT MATTERS: The light from existing fluorescent markers is difficult to detect through layers of tissue, so the use of such markers has been limited to dissected or surface tissue or to transparent animals, such as worms. This new marker emits light in the far-red part of the spectrum, which can better pass through living tissue. That means the marker can be used in live animals to help researchers track molecular and cellular activity, such as the rapid division of cancer cells, in real time.

METHODS: By inducing both random and directed mutations in the anemone protein, scientists altered it to create new compounds that are brighter than the original one. They then tested the new proteins both in frogs and in human cells, showing that they shine much more brightly than those previously available.

NEXT STEPS: Collaborators of the scientists will soon begin testing the proteins in mice. Although the markers aren't bright enough for whole-body imaging of humans, they might eventually be used to image human tumors that are near the surface of the skin, such as melanoma and breast cancer.

The First Diploid Sequence of an Individual Human

The highly accurate sequence suggests that our genetic code is five times as variable as we thought

SOURCE: "The Diploid Genome Sequence of an Individual Human"
Samuel Levy et al.
PLoS Biology 5: e254

RESULTS: Genomics pioneer Craig Venter and his colleagues have generated a highly accurate sequence of Venter's genome, one that includes the DNA sequences inherited from both his mother and his father.

WHY IT MATTERS: The genome sequence generated by the Human Genome Project, the massive, distributed effort to sequence human DNA that was completed in 2003, was a milestone in the history of biology. But the DNA sequence produced by the project represented just one set of chromosomes (every human has two sets, one inherited from each parent), and it drew on DNA samples from many individuals. As a result, it didn't reflect some of the variability between individuals. Venter's diploid genome suggests that genetic variation between individuals is approximately 0.5 percent, not the 0.1 percent that earlier sequencing projects suggested.

METHODS: In the new study, researchers used a method of gene sequencing called Sanger sequencing. The method is more expensive than newer approaches, but it generates longer strings of DNA that are easier to assemble into a complete genome.

NEXT STEPS: Venter and his colleagues plan to add phenotypic information, such as medical records and physical characteristics, to the database housing his genome. This will allow scientists to begin analyzing an individual's genomic information in the context of his or her actual traits. TR

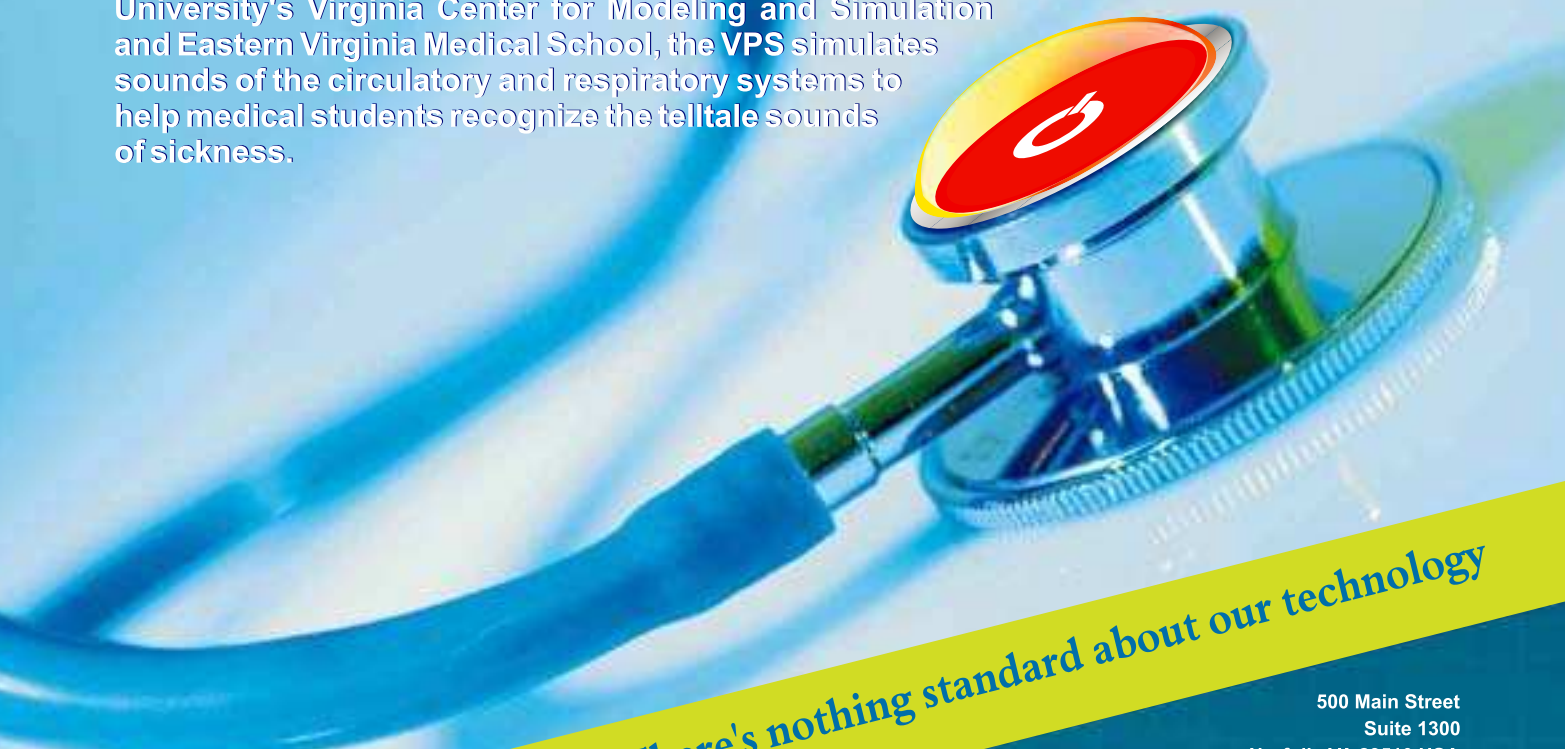
Imagination augmenting

REALITY in Virginia's Hampton Roads

Hearing is believing.

VPS - The Virtual Pathology Stethoscope

Created by a team of researchers from Old Dominion University's Virginia Center for Modeling and Simulation and Eastern Virginia Medical School, the VPS simulates sounds of the circulatory and respiratory systems to help medical students recognize the telltale sounds of sickness.

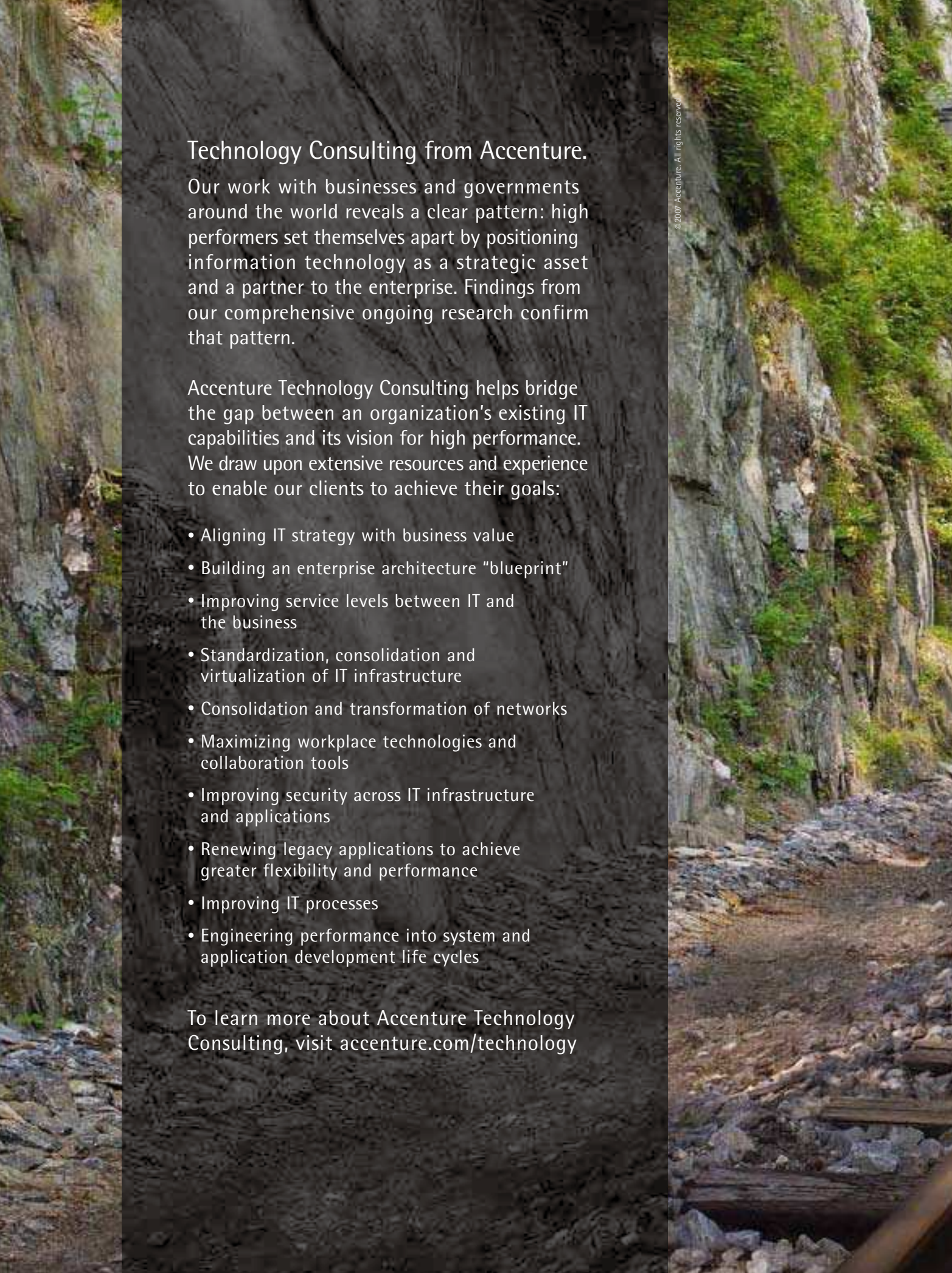


Virginia's Hampton Roads - There's nothing standard about our technology

500 Main Street
Suite 1300
Norfolk, VA 23510 USA
21 Enterprise Parkway
Suite 200
Hampton, VA 23666 USA
757.627.2315
hreda.com

VIRGINIA'S HAMPTON ROADS ECONOMIC DEVELOPMENT ALLIANCE®

Chesapeake Franklin Gloucester County Hampton Norfolk Poquoson Portsmouth Southampton County
Isle of Wight County James City County Newport News Suffolk Virginia Beach Williamsburg York County



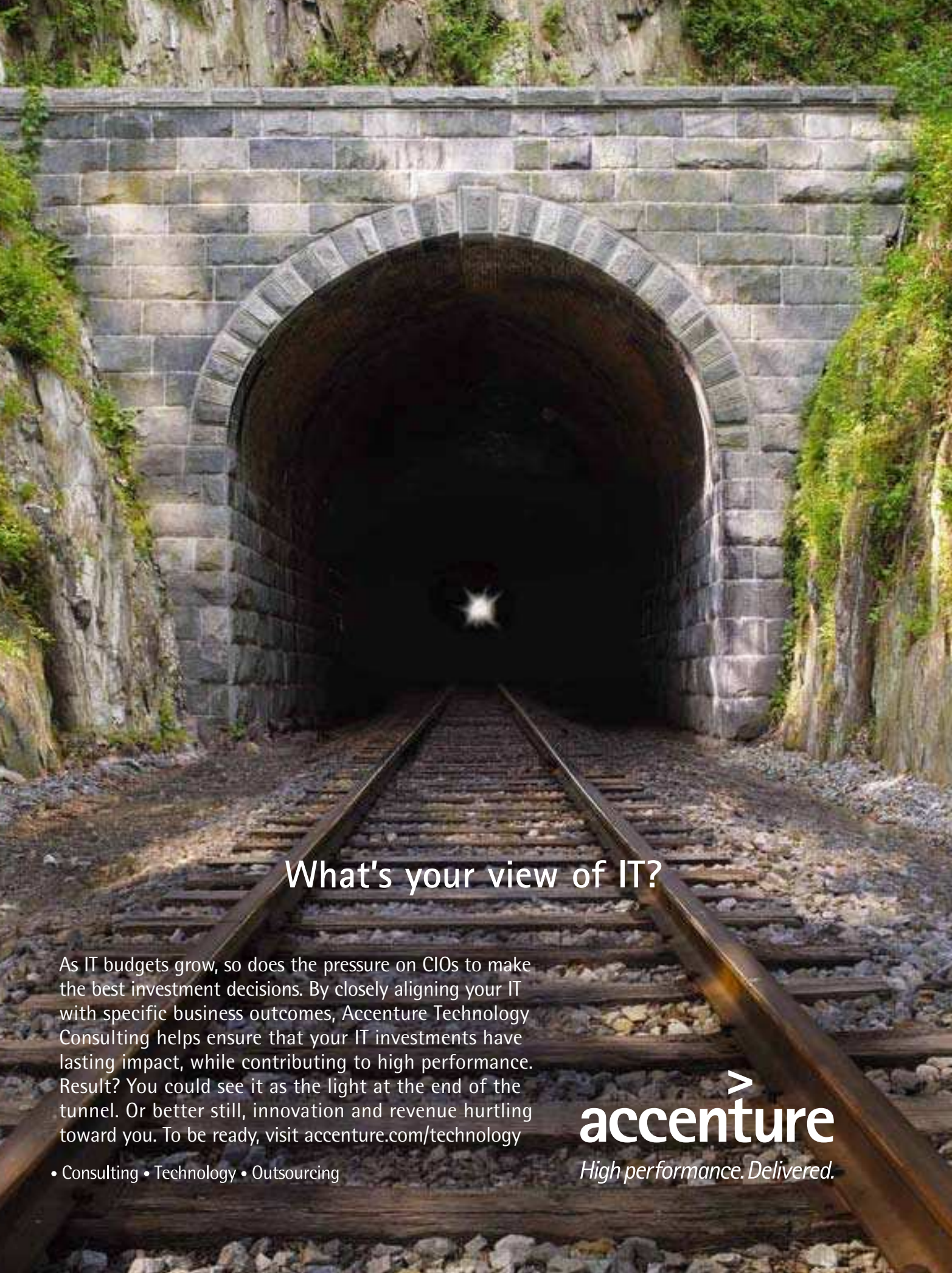
Technology Consulting from Accenture.

Our work with businesses and governments around the world reveals a clear pattern: high performers set themselves apart by positioning information technology as a strategic asset and a partner to the enterprise. Findings from our comprehensive ongoing research confirm that pattern.

Accenture Technology Consulting helps bridge the gap between an organization's existing IT capabilities and its vision for high performance. We draw upon extensive resources and experience to enable our clients to achieve their goals:

- Aligning IT strategy with business value
- Building an enterprise architecture "blueprint"
- Improving service levels between IT and the business
- Standardization, consolidation and virtualization of IT infrastructure
- Consolidation and transformation of networks
- Maximizing workplace technologies and collaboration tools
- Improving security across IT infrastructure and applications
- Renewing legacy applications to achieve greater flexibility and performance
- Improving IT processes
- Engineering performance into system and application development life cycles

To learn more about Accenture Technology Consulting, visit accenture.com/technology


What's your view of IT?
As IT budgets grow, so does the pressure on CIOs to make the best investment decisions. By closely aligning your IT with specific business outcomes, Accenture Technology Consulting helps ensure that your IT investments have lasting impact, while contributing to high performance. Result? You could see it as the light at the end of the tunnel. Or better still, innovation and revenue hurtling toward you. To be ready, visit accenture.com/technology
• Consulting • Technology • Outsourcing
accenture
High performance. Delivered.

The Bonfire of the Automated Trading Strategies

Computers' effects on markets remain controversial.

By Michael Patrick Gibson

In a single week in early August 2007, one of Goldman Sachs's hedge funds lost as much as $1.5 billion, about 30 percent of its value—a stunning loss, but by no means unique in the industry. In the same stretch, billions of dollars melted away from other top funds, too.

It all started with a high number of people defaulting on subprime loans (loans extended to high-risk customers). A few hedge funds, notably the Bear Stearns High-Grade Structured Credit Fund, had bought up these loans and repackaged them as credit derivatives to use as collateral in further transactions. As the derivatives tanked, investors were forced to sell off higher-quality securities—blue-chip equities such as Microsoft, IBM, and General Electric—in order to make up shortfalls in collateral. As the sell-off spread, the downturn accelerated into a nosedive *(see "The Blow-Up," p. 36)*.

Afterwards, some critics argued that the computer models used to value financial products had become so complex that buyers didn't know what they were getting; others held that computer-based trading strategies had exacerbated the sell-off. It was not the first time computers had been blamed for financial turmoil.

In a *Technology Review* article from February/March 1988 titled "Did the Computer Cause the Crash?", Lester C. Thurow, then dean of MIT's Sloan School of Management, argued that computer-driven trades were not at fault for

the market's single-day 508-point drop on October 19, 1987, a day now known as Black Monday. Of the '87 crash, Thurow wrote,

Computers make program trading possible because they can monitor more information faster and give the appropriate buy or sell orders long before a human could figure out what to do. However, the techniques of program trading and the software used to practice them are very much human creations. Like all expert systems, they merely mimic the actions of a human expert, in this case a broker. The computer can only respond to events that have already happened and act according to the rules built into the program by the broker. Thus, to blame the market's rapid fall on the fact that computers are automatically executing decisions that brokers would have made anyway is to make the common mistake of blaming the tool for the actions of the people using it.

If the computer did not cause the crash, what did? It depends on what you mean by the question. If by "cause" you mean the immediate catalyst of the 508-point decline on October 19th, the answer is that nothing or no one in particular caused it. Rather, it was the product of herd panic, not so different from the sudden panic that occurs among herds of antelope on the plains of Africa. To know why the crash took place precisely when it did would require understanding herd psychology, and even the best animal behavior experts don't pretend to know why antelopes (or humans) panic precisely when they do.

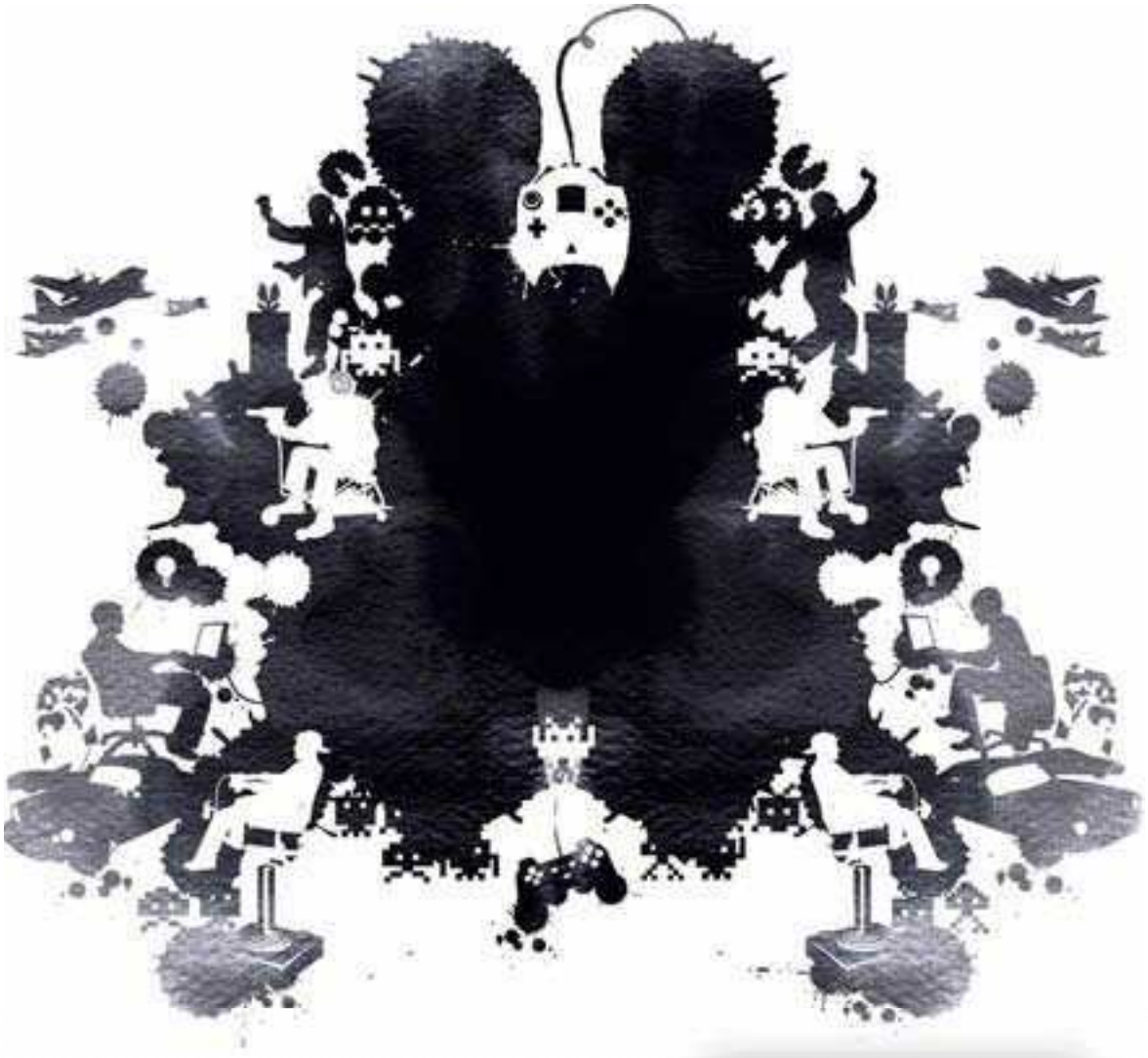
In the summer of 2007, computer models were still very much human creations. Once fund managers understood what was happening—too many computers were executing the same types of trades based on the same strategy—the models were altered, and in time, many losses were recovered. Still, the underlying cause of the panic is as debatable now as it was for Thurow in 1987:

Since higher interest rates mean constraints on economic growth, it was inevitable that the stock market would fall (whether slowly or quickly) to bring the price of stocks back into equilibrium with that of bonds. Whether stocks were being traded by computers or humans is beside the point.

As to how … markets were able to get so far out of line without an earlier correction, that is a complicated story. Put simply, it depends upon the age-old willingness to suspend one's critical judgment when lots of money is being made. It happened in the Dutch tulip mania of 1637. It happened again in the computerized stock market of 1987. TR

Technology Review (ISSN 1099-274X), Reg. U.S. Patent Office, is published bimonthly by the Massachusetts Institute of Technology. Entire contents ©2007. The editors seek diverse views, and authors' opinions do not represent the official policies of their institutions or those of MIT. Printed by Brown Printing Company, Waseca, MN. Periodicals postage paid at Boston, MA, and additional mailing offices. Postmaster: send address changes to Technology Review, Subscription Services Dept., PO Box 420005, Palm Coast, FL 32142, or via the Internet at www.technologyreview.com/customerservice/. Basic subscription rates: $34 per year within the United States; in all other countries, US$47. Publication Mail Agreement Number 40621028. Send undeliverable Canadian copies to PO Box 1051 Fort Erie, ON L2A 6C7. Printed in U.S.A. ABC audited

WHAT DO YOU SEE?



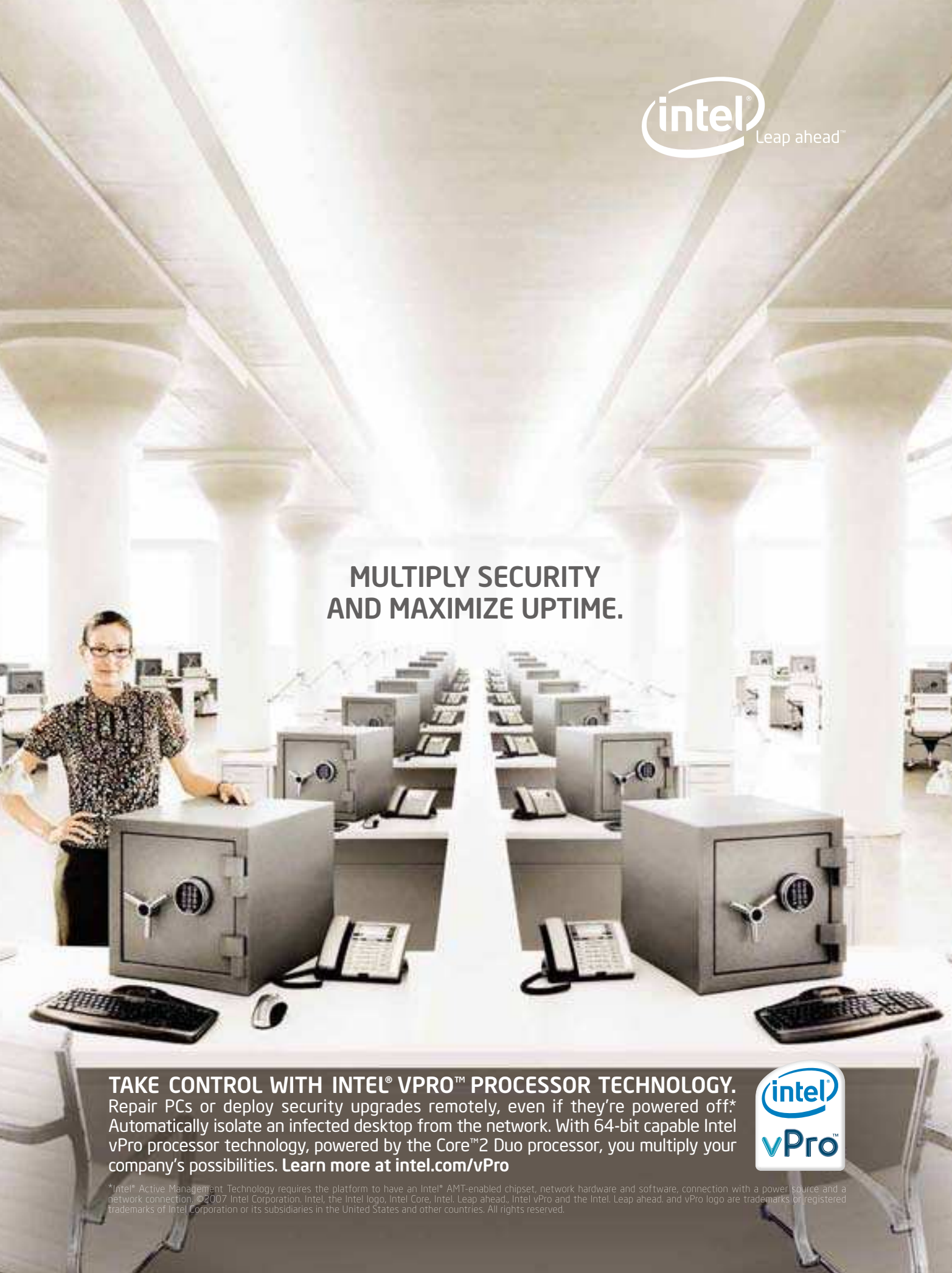
Imagination + Technology

In Orlando, we see aliens and tactical fighters, exploding cars and football stars. That's because industries built on imagination and innovation – like game development, digital production, and simulation – are booming here. And it's why forward-thinking companies and talented workers are thriving in an environment that exudes creative energy. Look closer! You'll see why Orlando is the place to turn your visions into (virtual) reality.

Call 407.422.7159

www.orlandoedc.com

Putting imagination to work®
ORLANDO


intel
Leap ahead™
MULTIPLY SECURITY
AND MAXIMIZE UPTIME.
TAKE CONTROL WITH INTEL® VPRO™ PROCESSOR TECHNOLOGY.
Repair PCs or deploy security upgrades remotely, even if they're powered off.* Automatically isolate an infected desktop from the network. With 64-bit capable Intel vPro processor technology, powered by the Core™2 Duo processor, you multiply your company's possibilities. Learn more at intel.com/vPro
intel
vPro™
*Intel® Active Management Technology requires the platform to have an Intel® AMT-enabled chipset, network hardware and software, connection with a power source and a network connection. ©2007 Intel Corporation. Intel, the Intel logo, Intel Core, Intel. Leap ahead., Intel vPro and the Intel. Leap ahead. and vPro logo are trademarks or registered trademarks of Intel Corporation or its subsidiaries in the United States and other countries. All rights reserved.